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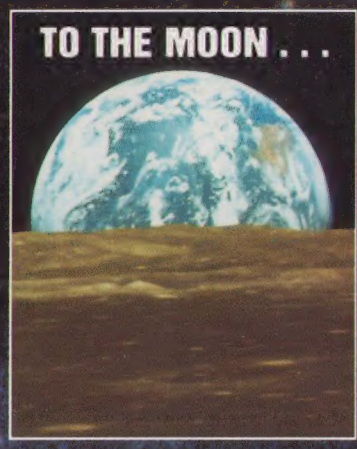

- The new breed of giant telescopes - will Australia have a share in one?
- Final countdown to the first manned Moon landing
- Seventy years of world-class science at Mt Stromlo

Our Galaxy

What lurks in the middle - is there a giant black hole?

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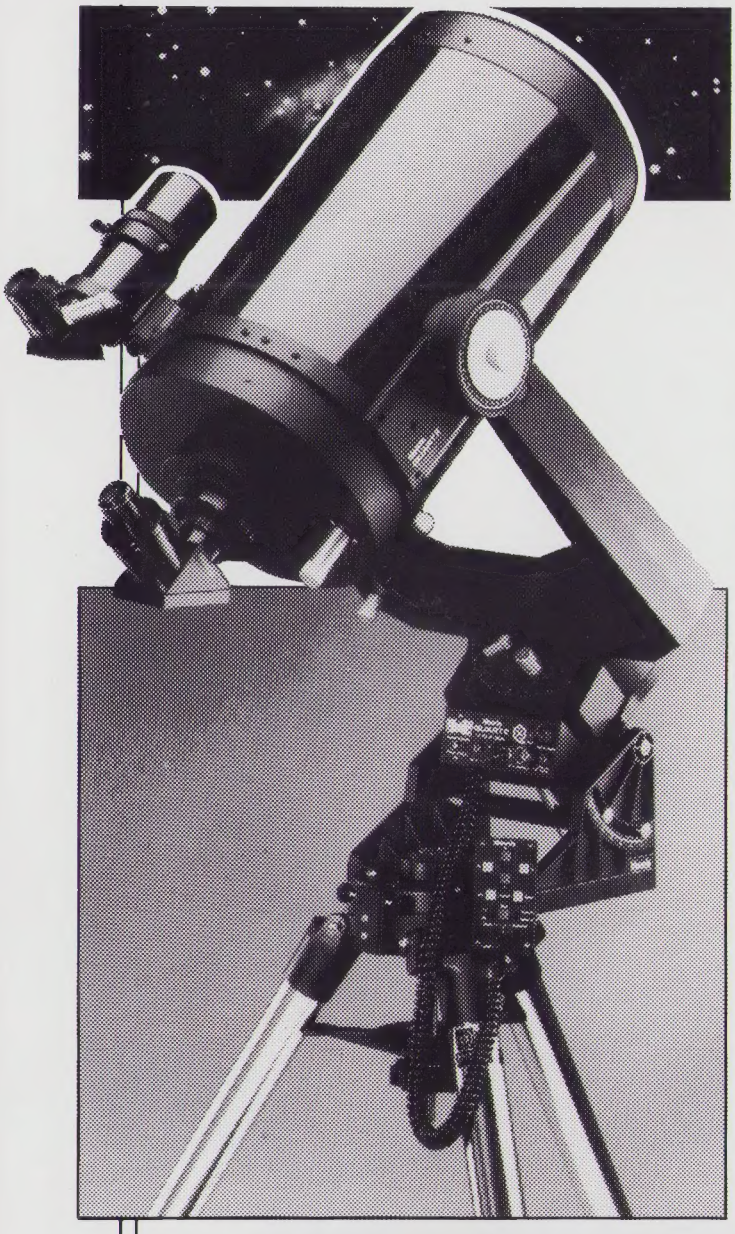

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THE LEADER'S EDGE

SKY & SPACE
The Only Astronomy & Space Magazine for Australia & NZ

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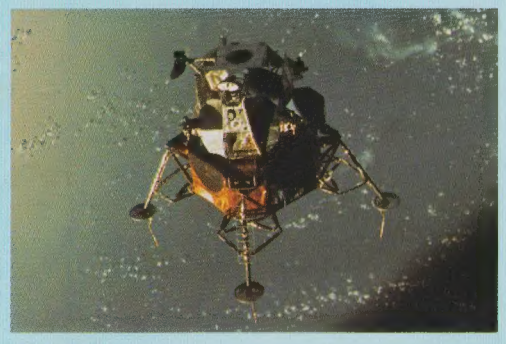

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ON THE COVER: What lurks in the centre of our galaxy? Is there, as some astronomers believe, a gigantic black hole, slowly devouring the surrounding stars and gas? The cover shows spiral galaxy M100; our galaxy would look a lot like this from the 'outside'. (D. Malin/©AATB) **Inset:** Twenty-five years ago, humans were about to land on the Moon for the very first time. (NASA)

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SKY & SPACE

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FROM THE EDITOR

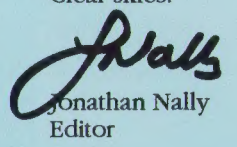
Australian success stories

This issue of SKY & SPACE Magazine is an interesting mixture of achievements by professional and amateur astronomers. Dr Jenny Nicholls from Sydney University's Research Centre for Theoretical Astrophysics brings us up-to-date with the latest thinking on what is going on at the centre of our Galaxy. Until very recently, this enigmatic region of space was hidden from our view by vast clouds of interstellar gas and dust. But with the newer technologies of the eighties and nineties, astronomers are piercing the dusty veil and uncovering all kinds of celestial secrets.

Another fabulous achievement is Australia's Mt Stromlo Observatory reaching its 70th anniversary, whilst still staying at the forefront of modern astronomy. During that period, many observatories have come and gone throughout Australia and the rest of the world, but Stromlo has prospered due to its tremendous theoretical and observational strengths. In this first of two parts, Ben Gascoigne covers the early years of Stromlo and discusses some of the characters and events which have shaped its development.

And our congratulations to Paul Camilleri, an amateur astron-omer from country Victoria, for winning this year's Berenice Page Medal for his outstanding contribution to astronomy. If you turn to page 38, you'll read how Paul has made many discoveries of novae and new variable stars in our Galaxy.

Clear skies!



Jonathan Nally
Editor

YOUR SAY . . .

Negative Attitudes

I was most disappointed to hear about the loss of the Mars Observer probe. Most people I spoke to (family, friends and workmates), regarding the missing probe came forth with comments like, 'What a waste of money, it could have been better spent feeding the starving millions', 'How will going to Mars benefit me?' or 'Who cares what's on another planet?' and so on.

Investigations into the cosmos always seems to have been met with varying degrees of this attitude, and I imagine other readers have struck this terra-centric ignorance.

I am at a loss as to how to convincingly defend various forms of space exploration. The best argument I can think of, (which only came to mind while writing this), would be to make historical comparisons with famous explorers and scientists. Many of them must have faced scepticism, funding difficulties, plain old bureaucracy and even persecution when trying to promote their vision.

Christopher Columbus appears to have suffered problems of finding a backer for his now famous voyage. Current space explorers face similar obstacles today - just look at how the US Congress deals with NASA.

I would be keen to see what other readers have to say, when dealing with such attitudes from their peers.

Ian Beagrie
Auckland

We share your views, as do, we're sure, most readers of SKY & SPACE. It is a pity that more people are not aware of the benefits - both tangible and intangible - of scientific exploration and endeavour. It is up to us all to convince those around us of the necessity to keep alive the spirit of adventure and wonder which fired our ancestors. Thank you for your letter Mr Beagrie - you win the free subscription.

Becoming a stargazer

Ten years ago I became interested in astronomy. I was about six years old at the time. If any other astronomers had of seen me then, they would have called me an 'armchair astronomer'. In 1986 I witnessed Halley's Comet and was thrilled - I could not wait for April! Unfortunately, April proved very disappointing.

Years flew by and astronomy turned

out to be just a passing phase, as I didn't turn my head skyward after Halley. But in April last year, as I was heading home with my family on a Friday night, we witnessed a bolide. I was leaning on the window, trying to go to sleep, when the whole sky lit up an eerie greenish blue - the bolide itself was a greenish white with a few specks following it.

As we live near Siding Spring Observatory, when we got home we informed the Observatory of our 'discovery'. Later the next day we were visited by a professional astronomer, Robert McNaught, who interviewed us. He then took me aside and we had an 'astronomical chat' about the splendour of the universe.

Now, almost a year later, I have three telescopes and many friends at Sydney Observatory (I board at a Sydney school). I have Robert McNaught (who is a famous name in astronomy and very well-respected everywhere) and SKY & SPACE to thank, for helping me to become a stargazer and not just an armchair astronomer.

John Lampe
North Sydney NSW

More software please

Thank you for producing a magazine for Australians. I have had a telescope for only a few years now, and have found your magazine very informative. I particularly like the Technical Tips and photo sections.

I would like to see more software reviews, in particular the public domain programs, some of which are quite good as well as being cheap. I have several and find them very useful.

Finally, I would like to say that the articles on Apollo and Hubble have been excellent reading and I look forward to more of the same.

Steve Chapman
Greystanes NSW

So much to learn

Please renew my subscription to your magazine for the next two years (cheque enclosed).

Over the last two and a bit years the magazine has been eagerly awaited - first by me, then my son (if he can get if off me!).

When I first subscribed I knew absolutely nothing of the subject of astronomy. I have learned so much from the magazine in the time I've subscribed but, of course, I know I have so much more to learn.

Thanks once again for such an informative publication. I look forward to receiving many more copies.

D. Drain
Elanora Heights NSW

Cone of confusion

In the Readers' Photos section of the December 1993 issue there is a peculiar lighting effect in part of Andrew Peter's photograph of the Orion Nebula.

I am referring to the image of a fairly bright star in the bottom right corner of the photo. There appears to be a couple of 'cones' of shadow, one on either side of the image, interrupting the scattering of light around it.

Can you say what arrangement of obscuring matter would produce such an effect? I haven't been able to figure it out.

Thanks for any ideas you might offer and thanks for an enjoyable magazine.

Gerry Teyhan
Tenambit NSW

The effect you spotted is not caused by obscuring matter out in space. It's an optical effect somewhere in the telescope system - Andrew thinks that it might be diffraction caused by light baffles in the tube. Ed.

A personal achievement

First, I'd like to say thank you very much for your magazine SKY & SPACE. It has brought me a lot of enjoyment and taught me a lot as well, as I am just a beginner. I'm still learning what and where things are, and your magazine has helped me greatly in my quest.

I was lucky enough to obtain a 10cm reflector telescope for $50 from a friend, who had heard that I loved our night sky and its mysteries. But as the price suggests, it is not in A1 condition. The mirrors are pitted, and the hour circle, declination circle and latitude indicator do not work. I think they just need recalibrating and oiling, as the former owner bought it second-hand, used it once and then left it alone for many years.

I have taken it to a Sydney dealer, who quoted me $300 to recalibrate it. They also suggested that I get rid of it and buy something better, but until I can afford to get a good one I will continue to use this telescope. Even with its disposition, I have been able to study the Moon, and also my best triumph of late, finding Jupiter and his four moons. I have been following Jupiter since March; this for me was a great achievement, and I have SKY & SPACE to thank for that. Thank you for showing me and teaching me - I look forward to learning and reading more and more in the future.

Thanks again guys - you're all excellent.

Lorraine Bell
Mortlake NSW

The writer of the best letter published in each issue will receive a free six-issue subscription to SKY & SPACE Magazine. Letters may be edited for brevity or clarity. Write to: The Editor, SKY & SPACE Magazine, 80 Ebley Street, Bondi Junction, NSW, 2022. We regret that due to high volume, we cannot individually answer all letters.

WIN A FREE BOOK!

Cambridge University Press have kindly provided a copy of the new book, *Atlas of Neptune*, by Garry E. Hunt and Patrick Moore, for SKY & SPACE to give away to one lucky reader.

Atlas of Neptune provides the historical background to the discovery of Neptune, its satellites and rings, and the details provided by the Voyager mission. *Atlas of Neptune* continues the authors' series of planetary *Atlas* books.

For your chance to win the free copy, all you have to do is send in a two-year subscription or renewal to SKY & SPACE. All two-year subscriptions and renewals received by last mail, June 20, will go into the draw for the book. The winner will be announced in our next issue.

Mail, fax and phone orders are accepted - there is an order form on page 48.

Winner of the April issue prize, *A View of the Universe*, was Mr S. Stratsianis, West Brunswick, Vic.

Are we seeing the end of the age of space exploration?

The 'Space Race' used to be very simple. It was a matter of the two superpowers slugging it out, like contending dinosaurs, to establish which had the better way of doing things. Being a dinosaur brought the obligation to behave like one: roar, stamp your feet, and 'show the flag', lest the smaller dinosaurs became restless and got ideas above their station.

The first sign of change was when the European nations decided, twenty years ago, to have a space programme of their own. The European Space Agency (ESA) grew rapidly and became a symbol of a more united (western) Europe. (A significant by-play to this initiative was the rejection by the Whitlam government of an invitation for Australia to join in.) By about 1989, ESA was third in expenditure on space, behind the USA and the USSR. But European space expenditure is now static or declining, under financial and political pressure from within Europe.

The 'Golden Age' of space exploration ended suddenly with the fall of the Berlin Wall. One of the two original dinosaurs realised that it was, in fact, extinct, and simply faded away. From a launch rate of well over 100 satellites per year, the Russian launch rate has dropped to below 50. The huge launch complexes are degenerating, the specialised launch service staff are now unpaid and underemployed, and key parts of a once integrated space infrastructure are now located in separate, non-cooperative republics.

The United States has a space programme devised on the basis of a world which no longer exists, and with its centrepiece a planned Space Station of vast expense, dubious scientific utility, and over-hyped commercial benefit. The USA has not developed a new heavy launcher in over a decade, and the Space Shuttle - although a marvellous technical achievement - is regarded as an expensive and inefficient means of getting into space.

So are we seeing the end of the age of space exploration? No, because 'Jurassic Park' is not the only show in town. On the western Pacific Rim, a number of dragons are stirring. With little fanfare, China, Japan, India, Pakistan - and more recently Taiwan, Korea and others - have been steadily developing advanced launch vehicles, satellite technologies, and scientific programmes. Their budgets are going up, not down, and they have the great advantage that almost 100% of every space dollar is put to productive use.

The small Japanese island of Tanegashima, has one of the most advanced launch centres in the world. Other launch complexes exist in China and India, and are being developed in both Koreas. For the past 15 years, the mainstay meteorological satellites used by Australia for cyclone warnings and routine weather forecasting have been Japanese: later this year, they will be complemented by Chinese spacecraft. In India, national television capacity increased a hundredfold through the launch of possibly the world's most advanced multi-functional satellite, designed and made in India. Pay satellite television services in Hong Kong, Thailand, Indonesia and elsewhere are glamour stocks in financial markets all over Asia, and are reaching an audience comprising about half of the world's population.

A Japanese H-1 lifts off from Tanegashima. (NASDA)

So far, most of these developments have occurred independently and with little regard for regional cooperation and mutual benefit. But in September, space ministers from countries in the Asian and Pacific regions will meet in Beijing to discuss proposals for a Regional Space Technology Programme under the aegis of the Economic and Social Commission for Asia and the Pacific, the UN body for the area. This could eventually lead to the formation of an Asia-Pacific organisation similar to the European Space Agency. Apart from projects which the initiative may generate directly, the model it poses - regional cooperation for mutual and peaceful benefits - offers a significant departure from the national programmes which were typical of earlier periods of the Space Age.

Many commentators of Australian space affairs believe that the 1975 decision not to join the European Space Agency dealt us out of the card game reserved for technologically advanced countries. But sometimes we get second chances. Last time round, Australia had only real estate to offer - in 1975 we had little ability to be a technological partner with the distant European countries. The situation now is rather different: in addition to proximity, we have the advantages of high capability in technical education, and scientific expertise. And thanks to careful nurturing through a small but persistent National Space Programme, we now have a small core of companies like Vipac, Auspace, British Aerospace Australia, Mitec - supported by the scientific and engineering skills of CSIRO - which (temporarily at any rate) puts us in the company of equals.

Once the dinosaurs died, they became extinct. But dragons can return to life after periods of dormancy. Australia now has one last chance to re-invent itself as a spacefaring nation, and fly with the dragons. **Jeff Kingwell.**

Jeff Kingwell is a writer and analyst on space technology and policy. He is Manager, Science, Applications and Public Affairs with the CSIRO Office of Space Science and Applications, Canberra.

The Year of the Family - an astronomical opportunity

The 'Year of the Family' is upon us. This era of changing lifestyles and values has sent those of us involved in education scurrying for definitions and inspirations that will provide a link between our schools the family.

Certainly, parents and children sharing and developing mutual interests is a great formula. This is evident with the success of the 'Life - Be In It' campaign. In that programme the emphasis was on healthy and recreational activity. Is there a parallel with an emphasis on knowledge, observation and awareness?

Popular fads run in cycles. Two in particular seem to enjoy prolonged life, perhaps because of the fascination of mystery and awe that surrounds them.

Stargazing can be a fun, family affair.

You don't need many guesses to identify them - dinosaurs and space. The first of these subjects is hard to find, but the second is all around us.

Now we are on the trail of what we could be looking for . . . almost in orbit in fact. Space, astronomy, stargazing, sky watching, everyday observations; how wide should our verandahs be, which trees to plant on the north side; making a sundial, using the Southern Cross or the sun as a compass, the changing direction of sunrise and sunset and varying noon altitude of the sun; recognition of constellations and star identification, the Zodiac groups; the lunar cycle and tidal ranges; ancient star cultures and myths and legends, and so on.

So many activities, so much scope for observation, and all possible after school or at weekends, when mum and dad are not working, and much of it possible with minimal or no expense. With homemade equipment and books from the library we can go a long way towards a joint family interest for all age groups, and we know that astronomy is a gateway to many areas of science and technology.

Family visits to the planetarium, programs run by the various observatories, or public sessions held by the various astronomical associations also are starting points.

So if you are looking for 'Year of the Family' activities, look up, look out, and reach for the stars! **Charles Treleaven.**

Charles Treleaven is Managing Director of the Journeyman Education Group, agents for the Starlab portable planetarium. Journeyman operate three Starlabs in Victoria. Tel: (03) 399 9089.

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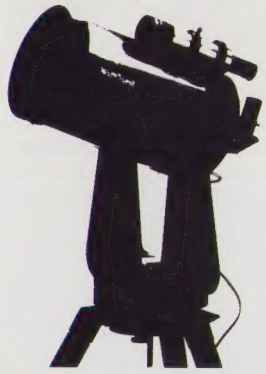

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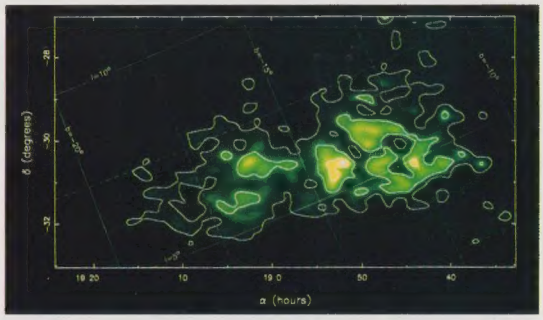
The Milky Way has a new neighbour

Astronomers in Cambridge have discovered the nearest neighbouring galaxy to our own Milky Way galaxy. They have identified a 'dwarf spheroidal galaxy' so close that it is effectively in collision with the Milky Way. The newly-discovered galaxy is in the process of being torn apart before being integrated into our Galaxy.

It has evaded detection up to this point because its members stars are scattered over a patch of sky more than 10 degrees across in the constellation Sagittarius. By direct observation, it is impossible to distinguish the stars belonging to the dwarf galaxy from the numerous foreground stars of the Milky Way because it lies in a part of the sky near to the galactic centre where there are vast star clouds. The new galaxy is 80,000 light-years from the Earth. By comparison, the Large Magellanic Cloud, previously regarded as the nearest galaxy, is 170,000 light-years away.

The discovery was made by a research student, Rodrigo Ibata, working at the Institute of Astronomy, University of Cambridge, with Dr Mike Irwin of the Royal Greenwich Observatory (RGO) and Dr Gerry Gilmore of the Institute of Astronomy. Photographic plates taken with the Schmidt Telescope at Siding Spring Mountain were used in conjunction with the Automatic Plate Measuring (APM) machine operated by the RGO, and the Autofib instrument on the Anglo-Australian Telescope, which can take the spectra of many stars simultaneously. The stars belonging to the dwarf galaxy can be identified by the fact that they lie in a limited area of the sky, share the same speed of travel and are at roughly the same distance. Their general physical characteristics also help to identify them - many are red giant stars.

The new Sagittarius dwarf galaxy seems to be similar to other dwarf spheroidal galaxies known to be 'satellites' of the Milky Way. Typically these galaxies are around 1,000 light-years across and contain a few million stars. (By comparison, the Milky Way is a hundred times larger and contains 200 billion stars.) However, the Sagittarius galaxy is already being torn apart and stretched by the gravitational pull of the Milky Way and is about 10,000 light-years across.

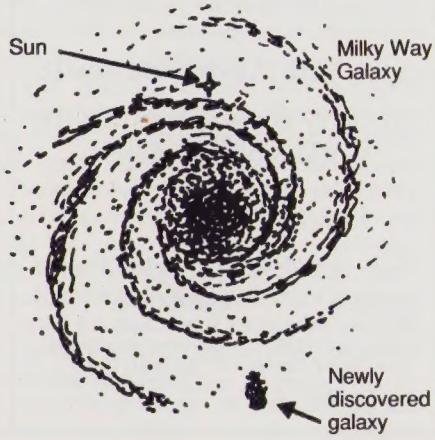


This false-colour computer image shows the spread of stars in the newly discovered dwarf galaxy. Stars in the Milky Way have been subtracted to reveal the new galaxy. The straight lines are galactic latitude and longitude lines. (R. Ibata & G. Gilmore Inst. of Astronomy, and M. Irwin, RGO.)

Currently, the Sagittarius dwarf galaxy is only 50,000 light-years from the centre of our Galaxy. It is stretched in a direction pointing towards the galactic centre and perpendicular to the main plane of the Galaxy. It is probably in a highly-elongated orbit around the Milky Way, currently travelling in a direction away from us at 153 kilometres per second, and is probably making its first close passage by the Milky Way in its 15-billion-year orbit. But it is unlikely to survive the encounter and has been caught in the act of disintegration. The Sagittarius dwarf is now so spread out that it cannot retain its stars against the tidal pull of the Milky Way. It will slowly disperse around the sky in the next few hundred million years.

There are several globular star clusters in the vicinity of the Sagittarius dwarf. The cluster known as M54 lies in the centre of one of two main clumps into which the galaxy appears to be split, and is listed at being at the same distance. It is possible that some of these globular clusters may actually be part of the Sagittarius galaxy, in the process of being incorporated into the Milky Way.

Until the present discovery, ten satellite galaxies of the Milky Way were known. Two of them, the Large and Small Magellanic Clouds, have been known from the earliest voyages to the southern oceans because they are clearly visible to the unaided eye. The other eight are so-called dwarf spheroidal galaxies, among the least luminous galaxies known. Astronomers had long suspected that there might be other such galaxies, perhaps disrupted by a close encounter with the Milky Way, and hard to find.

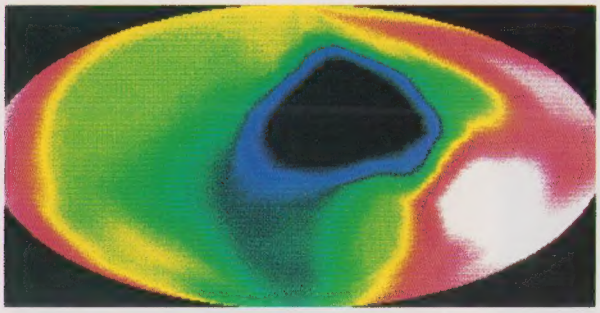


An inside view of the 'local bubble'

Astronomers have been aware for some time that our solar system lies in a region where the density of interstellar gas is much lower than average. This 'local bubble' was probably blown out by the shock wave from one or more supernova explosions that occurred in our part of the galaxy in the remote past. Now Colin Barber and Bob Warwick of Leicester University have used information collected by the extreme ultraviolet (EUV) wide-field camera on the ROSAT satellite to create a colour-coded map of the structure of this bubble.

The mapping technique relies on the fact that certain types of stars, for example white dwarfs, emit particularly intense EUV radiation, which in turn is absorbed very strongly by 'cool' hydrogen and helium gas making up the bulk of the local interstellar medium. The degree to which the EUV radiation from a distant star is absorbed provides a measure of the amount of gas along the line of sight from our solar system to the star.

By studying many such stars in different directions in the sky it is possible to deduce the overall distribution of the gas. Fortunately, early on in the ROSAT mission an all-sky survey for EUV-emitting objects was successfully completed with the wide-field camera. This led to a catalogue of 383 sources, representing a 30-fold increase in the number of known EUV stars. It is these newly-discovered EUV sources which serve as the probes of the local



The view looking out - an 'all-sky' map of the ultraviolet sky, showing the distance from the Sun to the edge of the 'local bubble' in which our solar system lies. The closest part of the bubble wall is colour-coded black, and the furthest part is coded white. Courtesy C.R. Barber & R.S. Warwick, University of Leicester.

interstellar medium.

The colour-coded map shows the distance to the boundary of the local bubble in an all-sky representation in which the plane of the Milky Way runs horizontally with the galactic centre in the middle. The key shows distances to the edge of the bubble in light-years. At the bubble boundary the gas density rises quite sharply, by at least a factor of 10, but with only 500 atoms per litre, the walls of the bubble remain fairly tenuous structures.

The bubble boundary is nearest to us in a direction roughly towards the galactic centre, where an extended dust cloud (known as 'Tinbergen's Cloud') lies only about 30 light-years away. The nature of this cloud is not well understood but it appears that its relative motion has led to a considerable deformation of the local bubble. The furthest extent of the bubble (about 500 light-years - coded white) is in the direction of the star Beta Canis Majoris, where the bubble wall is permeated by tunnel-like structures.

What if gravity were wrong?

For a body that is bound to a system by gravity - such as a planet in our Solar System or a star in a galaxy - the maximum speed at which it can travel and still remain bound is related to the total mass in that system. The more mass there is in the system, the faster the body can go without escaping and wandering freely through space.

The large speeds at which stars move within galaxies suggests that there is much more matter present than we see in the form of stars and gas. If this were the only matter present, there would be insufficient mass to keep the stars from flying apart. Astronomers call the unseen matter required to bind the galaxies together, dark matter.

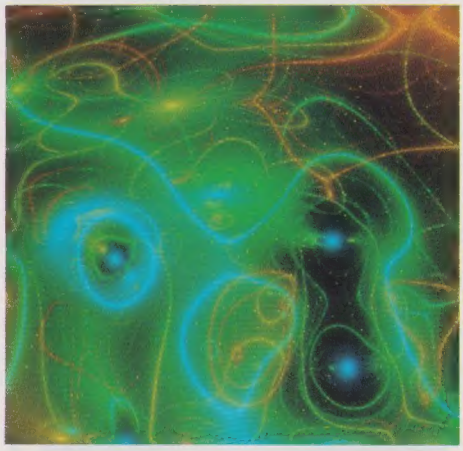
However some scientists contend that dark matter does not exist, and that what we are seeing comes about because Newton's law of gravity breaks down at large distances.

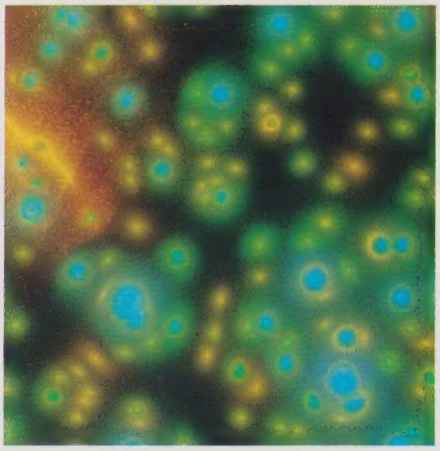
While we know that Newtonian gravity works very well within the Solar System, there has been no independent determination of the law of gravity over galactic dimensions and so the various non-Newtonian gravities have been difficult to refute. Dr Mark Walker, a Fellow of the Research Centre for Theoretical Astrophysics at the University of Sydney, has demonstrated a failure of one such theory (Weyl Gravity) and placed tight restrictions on all other non-Newtonian gravities.

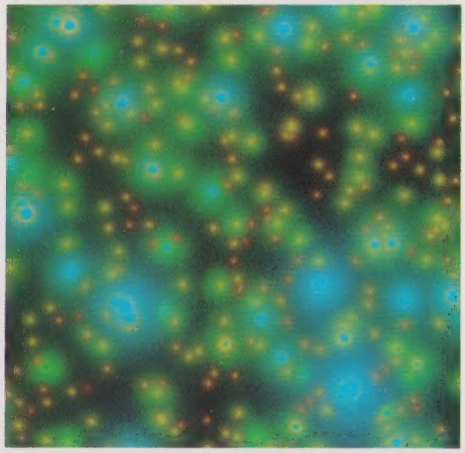
Dr Walker considered the manner in which light is deflected by gravitational fields in various different theories. Large amounts of mass can deflect light from its straight line course; for instance, the light from a distant galaxy or quasar can be deflected by another galaxy lying between us (the observer) and the distant light source. This deflection - or lensing - leads to changes in the apparent sizes and shapes of distant galaxies so that they appear either fainter, or brighter, or distorted.

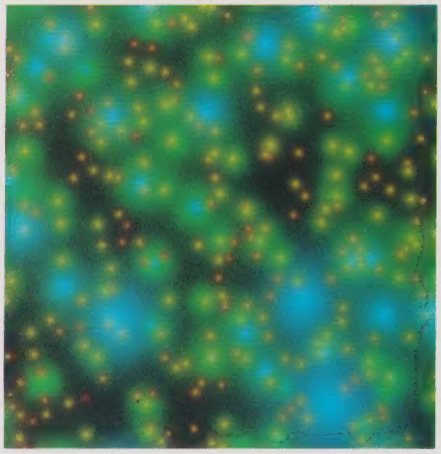
For Newtonian gravity, these changes are small - in agreement with observations - but in other theories they can be extremely large. In particular,

How our universe would appear if the light from distant galaxies was bent by different versions of gravity. Top left shows the universe with a completely different kind of gravity to the one we are used to; top right is a modified type of normal gravity; bottom right is the universe with no gravity; and bottom left is normal gravity. Check your skies tonight!









almost any non-Newtonian gravity which might offer an alternative to dark matter is expected to alter the optical properties of our Universe substantially. Thus the appearance of distant galaxies is a useful test of the law of gravity. That galaxies appear exactly as we would expect them to under Newtonian gravity implies that to be acceptable, alternate theories of gravity must mimic Newtonian gravity over very large distances.

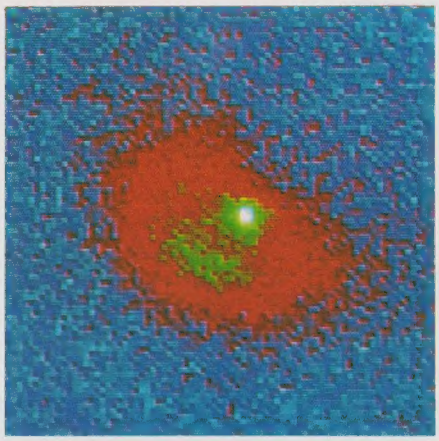
Keeping track of Halley

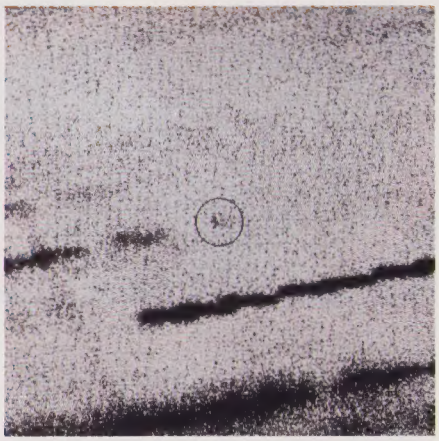
Astronomers at the European Southern Observatory (ESO) in Chile have taken an image of Halley's Comet at a distance of 2,820 million kilometres from the Sun - about as far away as the planet Uranus. It recently passed the halfway mark towards the most distant point of its 76-year orbit.

The new image shows the nucleus to be an extremely faint point of light without any surrounding dust cloud. It appears that the surface is now completely frozen and the comet has ceased to emit dust and gas.

The image was difficult to obtain and is close to the limit of what is possible - it's like trying to spot a black golfball during a late evening game, from a distance of 12,000 kilometres!

At Halley's present distance from the Sun, the intensity of the sunlight is over 350 times fainter than here on Earth. The surface of the cometary nucleus is very dark; it reflects only 4% of the infalling sunlight. The light astronomers see coming from Halley is therefore extremely faint: the nucleus is about 160 million times fainter than the faintest star that can be seen with the unaided eye.





The changing visage of Halley's Comet. Left: the strange outburst spotted in February 1991 - was it an internal explosion, or did the comet hit something? Right: Halley in 1994 - a frozen ball of dirty ice, 2,820 million kilometres away.

A long exposure was needed to catch enough light to show the comet; even with a very sensitive CCD camera fitted to the ESO New Technology Telescope in Chile, the shutter had to be left open for a total of 3 hours 45 minutes. During this time, around 9,000 photons (particles of light) from Halley were registered. Almost one million photons were simultaneously received in the same direction from the luminous atmosphere of the Earth. They had to be carefully 'subtracted' before the comet could be seen.

The measured brightness (visual magnitude 26.5 ± 0.2) closely corresponds to what would be expected, if it results from sunlight being reflected from the nucleus alone. This suggests that there is little, if any, dust left around the nucleus and that its surface layers are now completely frozen.

The observation shows that nothing is left of the great mass of dusty material, estimated at one million tonnes, that was thrown out during a completely unexpected outburst in February 1991.

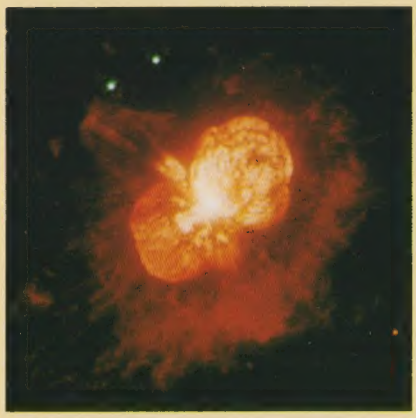
Halley will continue to move outwards through the solar system at decreasing speed. Thirty years from now it will reach the turning point (the 'aphelion') of its elongated orbit, almost 5,300 million kilometres from the Sun. Although it will be 15 times fainter than at the present time, it should still be possible to see it with some of the new giant optical telescopes coming on line. Halley's next return to the inner reaches of the solar system will occur in the year 2061.

A star on the brink of destruction

NASA's Hubble Space Telescope has taken the most detailed look yet at the supermassive star Eta Carinae, in the southern constellation of Carina.

Eta Carinae is approximately 150 times the mass of the sun, and about 4 million times brighter, making it one of the most massive and most luminous stars known. It is highly unstable, and prone to violent outbursts. The last of these occurred in 1841, when despite its distance (over 10,000 light-years away) Eta Carinae briefly became the second brightest star in the sky.

The ghostly red outer glow which surrounds the star is composed of the very fastest moving of the material which was ejected during last century's outburst. The material is moving at more than three million kilometres per hour. The blue-white nebulosity closer in consists of ejected stellar material. The new picture shows that this structure consists of two lobes, one of which (lower left) is moving toward us and the other of which is moving away. *(J. Hester/Arizona State Uni./NASA.)*



Australia's eye (and ear) on the Sun

Observations of the sun are a vital component in forecasting disturbances to the Earth's magnetic field and the ionosphere (a charged layer in the

atmosphere important for radio communications). These include not only observations in visible light of sunspots and solar flares but also observations from space with X-ray telescopes and from the ground with radio telescopes.

The Culgoora Radiospectrograph is a radio telescope which has played, and continues to play, an important role in forecasting. The instrument is located at the Ionospheric Prediction Service (IPS) Culgoora Solar Observatory on the CSIRO Australia Telescope site near Narrabri in northern New South Wales. The Radiospectrograph was originally built by CSIRO and used for pioneering scientific studies of radio bursts from the sun. The observations also proved of interest to IPS who obtained access to the data in real-time from CSIRO. By 1986 the Radiospectrograph had exhausted its scientific potential and the instrument was transferred to IPS for use in solar-terrestrial forecasting.

In 1991, IPS commenced work on a major upgrade to the instrument to replace electronics which were obsolete and had degraded badly in performance. The new Radiospectrograph was brought back into operation in May 1992 and has been performing its role effectively since then. It has enabled IPS scientists to witness solar radio bursts over a large range of frequencies. In particular, they have obtained excellent observations of Type II bursts, produced by electrically charged material ejected from the sun after a solar flare, perhaps on its way to produce a disturbance here on Earth. By analysing the way in which the radio frequencies change with time, IPS can make an estimate of the speed at which the cloud of material is travelling outwards from the sun - important information in making forecasts of terrestrial disturbances.

The Culgoora Radiospectrograph has generated considerable interest from overseas. IPS is collaborating with KEL Aerospace, an Australian high-technology company, in the production of a commercial version of the spectrograph.

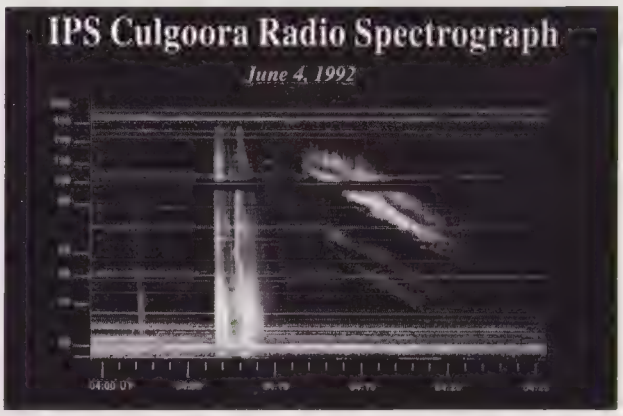
Alpha Centauri may be sending comets our way

As many as 100,000 comets may be set on course for the inner Solar System as the star Alpha Centauri sweeps through the Sun's neighbourhood, according to research published in the March 1994 issue of the *Quarterly Journal of the Royal Astronomical Society*.

Robert Matthews, who is a visiting fellow in the Department of Computer Science at the University of Aston, Birmingham, calculates that some of the comets may already be on their way in. Their arrival will boost the risk of the Earth suffering an impact with potentially disastrous consequences. The good news, however, is that although the comets may have begun their journey, they will not arrive for around another 20 million years.

The sources of the comets is the so-called 'Oort Cloud', a reservoir of billions of comet nuclei in a spherical shell surrounding the Solar System. No-one has ever seen the Oort Cloud directly, but comets with huge orbits are thought to originate there. The Oort Cloud extends out perhaps as far as two light-years - half-way to the nearest star. Comet nuclei from the cloud get projected into our part of the Solar System by gravitational kicks from passing stars.

In the region of space within about 15 light-years of the sun there are about 50 known stars. Astronomers believe they have a good understanding of what is



A particularly large solar radio burst, recorded by the IPS Radiospectrograph at Culgoora in NSW. A large but short-lived burst of radio energy across the entire frequency range can be seen between 04:07 and 04:10 (in Universal Time), whereas a Type II burst began at 04:12 and lasted ten minutes, gradually lowering in frequency as it faded. Type II's indicate a stream of solar material heading towards the Earth.

ASTRO NOTES

A hiccup for VLT? The European Southern Observatory has locked horns with a local Chilean family over 'ownership' of the land on which its new telescope complex will be built. In 1988, the Chilean Government donated 725 square kilometres of land around Paranal Mountain for ESO to build the Very Large Telescope (VLT) - a collection of four, giant 8-metre optical telescopes and a host of smaller instruments. However, early last year the descendants of Admiral Juan Jose Latorre claimed that a part of the land which was donated to ESO and, in particular, the site upon the VLT is to be constructed, had earlier been given to the admiral in return for his services to his fatherland during the Chilean wars of the late 19th century.

The Latorre family has instituted several legal challenges to prevent ESO from continuing construction and to evict them from the mountain top, however ESO is countering with diplomatic moves to uphold its claim to Paranal. According to ESO, the agreement between ESO and Chile has special legal status and is not subject to normal domestic Chilean law.

Dust in their sights. A team of astronomers from the United Kingdom, France and Germany have for the first time discovered an immense cloud of dust in a distant quasar. It was found when the astronomers observed the quasar with telescopes sensitive to radiation with a wavelength of 1mm. They found that the distant quasar is emitting much more energy than expected at mm-wavelengths and deduced that there is a dust cloud present 100,000,000 times more massive than the sun.

A simple explanation for the dust cloud and the energy source warming it involves a large group of newly-formed stars, many millions of times larger than the Orion Nebula. Within this region, 1,000 solar masses of new stars form every year. The total mass of the galaxy is probably 1 million million solar masses. One of the team members, Dr Richard McMahon, says 'We may be seeing this quasar and its surrounding galaxy only a few hundred million years after it switched on. If this is true, we may be seeing it as it first shines through the dusty cloud that has covered it while it was forming'.

Shedding light on dark matter. The MACHO team searching for dark matter (see 'The Search for Dark Matter, Oct '93, p20) has measured the brightnesses of eight million stars in their first year of data. They have spotted one almost certain MACHO (Massive Compact Halo Object), and they expect in the next few months to be able to estimate the density of MACHOs around our galaxy.

going on here, in what they call the 'solar neighbourhood', because the movements and distances of these nearby stars have been measured accurately. Matthews has collected the latest information and has used it to compute the past and future positions of the stars.

It turns out that we are entering a period rich in close encounters between the sun and its neighbours. Over the next 45,000 years, no fewer than six stars will approach closer than 4.22 light-years, the distance today of Proxima Centauri, the star nearest our sun.

Most of these stars are insignificant 'dwarf' stars, with only one-tenth the mass of the sun. But two - the double star Alpha Centauri A and B - have masses comparable with that of the sun. This raises the possibility that their gravitational fields may have a significant effect as they sweep in at about 120,000 kilometres per hour to their closest approach at a distance of 3.12 light-years.

Matthews says that the two stars will have negligible effects on the orbits of the planets round the sun, but they may already be imparting a gravitational jolt to the Oort Cloud of comets - enough to set in train a course of events with possible dramatic consequences for our descendants in the remote future.

The giant elliptical galaxy NGC1399 in the constellation Fornax. Astronomers Magda Arnaboldi and Ken Freeman (Mount Stromlo Obs.) have measured the motions of dozens of planetary nebulae (some of them circled) in the outer regions of the galaxy in an effort to determine its total mass. It turns out that the galaxy's visible matter - stars and hot gas - accounts for only 10% of the mass required to sustain the rapid motions of the nebulae. This is yet another piece of evidence for the existence of 'dark matter'.

A giant galaxy with a dark secret

An international team of astronomers led by two scientists from Mount Stromlo Observatory near Canberra, have made new observations which indicate that 90% of the mass in a distant giant galaxy may be 'dark matter'.

Magad Arnaboldi, Ken Freeman and their colleagues, were able to observe the individual motions of 37 extremely faint planetary nebulae in the outskirts of NGC1399, a giant elliptical galaxy 50 million light-years away in the Fornax cluster of galaxies. Planetary nebulae are shells of gas surrounding old stars. Because they are small and very far away, they have a planet-like appearance, although that are not connected with planets in any way.

Giant elliptical galaxies are usually found at the centre of vast clusters of smaller galaxies. Astronomers believe the giant ellipticals formed by the aggregation of smaller clumps of matter, thereby making them larger and larger as time progresses. The individual clumps would produce tidal effects on each other, leading to different motions in different parts of the galaxies. A crucial test of this theory is to measure how matter moves in the outskirts of these huge galaxies.

Planetary nebulae are useful beacons in the outer regions of galaxies. Although they exist for only a short time in astronomical terms, there should be several hundred of them present in the outer regions of any giant galaxy at any one time. Also, planetary nebulae emit most of their light at a particular wavelength, making them easy to spot.

The team of astronomers had used this technique before on closer galaxies, but never on one this far away. At the distance of NGC1399, the planetary nebulae are extremely faint and out of the range of most telescopes.

Arnaboldi, Freeman and their co-workers used the 3.5-metre New Technology Telescope of the European Southern Observatory (ESO) in Chile for their observations. The NTT is equipped with a main mirror that can be adjusted to compensate for the blurring effect of the Earth's atmosphere. When used together with a device called the ESO Multi-Mode Instrument, which can observe many objects simultaneously, the astronomers were able to make the most of their three nights of observing time.

Their observational strategy paid off, and they were able to obtain data for 37 planetary nebulae in NGC1399. They found that the nebulae are in rapid motion, clearly indicating a fast rotation speed for these parts of the galaxy.

Working backwards from these velocity measurements, the astronomers are able to determine how much matter must be present in the galaxy to sustain the rapid motions. It turns out that the visible matter - stars and hot gas - comprise only about 10% of the required mass. This is yet another clear indication of the presence of dark matter in the universe, although its exact nature is yet to be resolved.

A moon with a view

Galileo, the Jupiter-bound space probe, has surprised scientists by capturing an image of a tiny 'moonlet' near the asteroid Ida, which it passed on August 28, 1993. This is the first conclusive evidence of a moonlet accompanying an asteroid.

Ida is a Koronis-type asteroid, about 56 kilometres along its long axis. The

The asteroid Ida (above) with its moonlet, designated 1993 (243) 1. Galileo was 10,000km from the pair when it took this image of the 56km-long asteroid and its 1.5km-wide moonlet. An enlarged view of the moonlet (left) shows it to be rugged and cratered. (NASA)

size of the moonlet is uncertain, as scientists do not know yet exactly how far it was from the spacecraft during the encounter. It is believed to lie between Ida and Galileo, which would make it around 1.5 kilometres across.

Ida is a heavily cratered, irregularly-shaped asteroid in the main asteroid belt between Mars and Jupiter. It is the 243rd asteroid to be discovered since the first one was found at the beginning of the 19th century. The small moonlet, has yet to be named by astronomers. It has provisionally been designated '1993 (243) 1' by the International Astronomical Union.

Although the moonlet appears to be 'next' to Ida in the photograph, it is actually nearer the spacecraft. Combining the image with data from Galileo's near-infrared mapping spectrometer, the science team estimates that the object is about 100 kilometres away from the centre of Ida. (Galileo was just over 10,000 kilometres from Ida when it took the image.)

Galileo is on its way to Jupiter, where it will arrive in December, 1995, after a journey of 3.8 billion kilometres.

UWS Observatory takes shape in Sydney's west

Australia's latest teaching observatory is just months away from completion at the Werrington North campus of the University of Western Sydney, Nepean. The Observatory will comprise a lecture theatre with space for 50 students, offices, and a 6.5-metre dome housing a fork-mounted 60cm Ritchey-Chretien telescope. There will also be two outside observation areas for tripod-mounted telescopes.

The new observatory is the brainchild of Dr Graham White of the Faculty of Science and Technology at UWS, Nepean. Through his efforts, funding was secured for the Observatory from the Commonwealth Department of Employment, Education and Training, with matching funding from UWS, Nepean, and seed grants from the Faculty. The Observatory will be accessible to all university members and be prominent to the local community.

The Werrington North site provides relatively dark suburban skies and the potential to protect the ambient light environment from new buildings that will eventuate.

The main telescope will be housed in the dome, 4.7 metres above ground level. The telescope pier is set to bed-rock and is vibration isolated from the building itself. The 610mm f/3.5 primary mirror and the 203mm secondary will be of Pyrex and Zerodur respectively.

The Observatory and its telescope will be used to support the University's Liberal Arts astronomy elective programme as well as support various undergraduate programmes in the applied physics degrees. Adult education programmes, through the University's Continuing Education West, have been

On with the dome! The new observatory of the University of Western Sydney, Nepean takes shape.

running for the last three years and the Observatory will serve as a venue to strengthen that activity.

An important role of the Astronomy Centre will be promoting the University within the local school community by promoting astronomy and science. These programmes are designed to acquire quality students for the University in the future - there are an estimated 250,000 students in Sydney's west.

The University of Western Sydney, Nepean, is a member of a 'network university' servicing the western region of Sydney. S&S

The Riddle in the Middle

by Jenny Nicholls

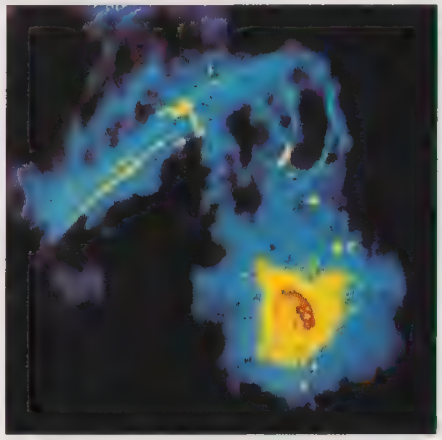
Is there a black hole at the centre of our Galaxy? Are we any closer to understanding this bizarre region of space? Dr Jenny Nicholls explains . . .

What lies at the centre of our Galaxy? Is it a black hole, millions of times the mass of our Sun? Is it a region of star formation where massive stars are born, live for only a few million years, and die in brilliant explosions of energy? Or is it a combination of both?

Almost 400 years of observations with optical telescopes told us nothing about the heart of the Milky Way, despite advances in sensitivity that have allowed us to see astronomical bodies with unprecedented clarity and accuracy. Thick interstellar clouds of dust and gas obscure the visible light emitted by the Galactic centre. It took the invention of radio astronomy to begin to pierce the dusty veil.

The first radio waves found coming from outside the solar system were identified as originating in the Galactic centre. This discovery, in 1932, was both the birth of radio astronomy and of the study of this previously unseen region of space. Today, with modern radio, X-ray and gamma-ray telescopes, and the new infra-red detectors in operation at optical observatories, a wealth of new detail is available, and scientists are beginning at last to unravel the riddle in the middle of the Galaxy.

Above: *'Baade's window' - looking toward the centre of the Galaxy, a view which is blocked by stars and dust (David Malin photo; courtesy AATB).* ***Below:*** *Sagittarius A, the strange body near the galactic centre (N. Killeen image; courtesy NRAO/AUI.)*

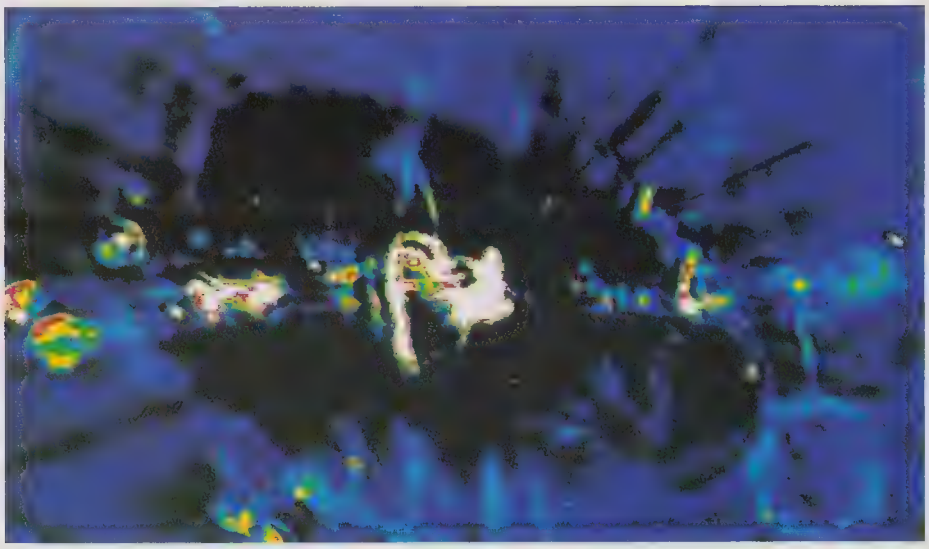


Sagittarius A

If there is a massive black hole in our Galaxy, one that is more than one hundred times the mass of our Sun (one hundred solar masses), it will lie in a region called Sagittarius A, the brightest source of radio waves in the Sagittarius (Sgr) sector of the sky. In early radio maps, Sgr A looked like one large structure, but with modern equipment and techniques it has been resolved into several parts.

A radio map of the eastern part (Sgr A East) shows a large, almost complete ring, or shell, of radio emission. The emission is produced by electrons travelling very close to the speed of light, spiralling about in a strong magnetic field. The shell structure and the type of emission imply that the ring we see is most likely the wall of an expanding bubble of hot, X-ray emitting gas, created when a massive star exploded at the end of its life - in other words, a supernova remnant. Sgr A East lies just behind and to the east of the Galactic centre.

The central 15 light-years of the Galaxy are filled with warm, dense clouds of molecular dust and gas which contain both individual atoms and simple molecules. These clouds form a spinning,



Left: *The enigmatic environment of the galactic centre. The ring at bottom right is thought to be the remnant of an exploded star; the thin vertical line above it has been nicknamed 'the Snake'. In the centre is Sagittarius A, a region of high radio emission - merged into its upper lobe is Sagittarius A*, which possibly is the exact centre of the Galaxy. Other features on the map are supernova remnants and regions of ionised gas.*

flattened disc called the 'circumnuclear disc'. Some astronomers believe it is not a continuous structure like a compact music disc or LP record, but that it is made up of about four streamers of gas that are being pulled into the very central region of the Galaxy. The clouds are not dense enough to hold themselves together against the gravitational attraction of the accumulated mass at the very centre, so they are torn apart, or tidally disrupted, into streamers.

All this activity means that the circumnuclear disc is a very dynamic object in Galactic terms, constantly changing as streamers of gas are dragged into the centre and clouds falling in from further out are disrupted to form new streamers. Rapid change in Galactic terms, however, means a timescale of about 10,000 years, so no significant change to the disc is expected during our lifetimes.

At the centre of the disc is a cavity filled mostly with neutral atomic gas, where molecules have been torn apart into their constituent atoms by the ultraviolet light from nearby stars.

However, the feature which dominates the cavity consists of ionised gas - gas that has been heated until one or more electrons have been stripped off the atoms. It is thought that several of the streamers have been pulled down into this region and become ionised. Because ionised gas emits radio waves across a huge bandwidth, but neutral gas emits only at very precise frequencies, in many maps the streamers stand out from the background and look like a mini-spiral, right at the heart of the Galaxy.

The Stellar Component

Stars are spread right throughout the entire Galaxy. The number of stars per cubic light-year, the stellar density, increases steeply towards the Galactic centre.

It appears that there are two populations of stars that form the central cluster. One population is simply the core of the galactic bulge, reaching a peak density about three light-years from the centre of the Galaxy. These stars are old and small.

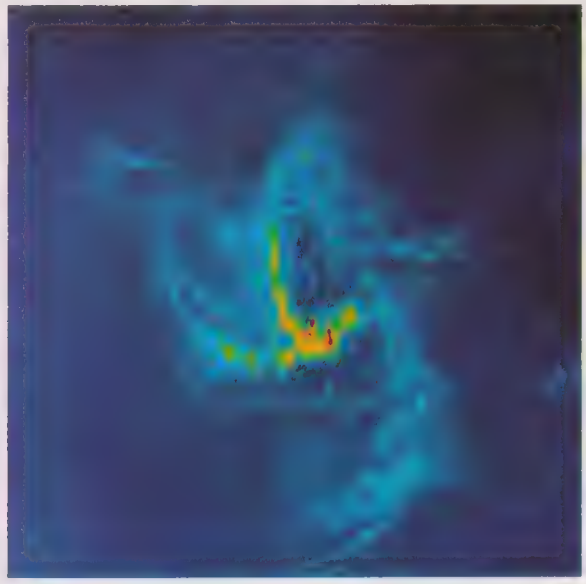
The other population is more mysterious. They form a comparatively tiny cluster of hot, young stars right at the centre of the bulge. Hot, massive stars have short lifetimes, so any that formed as part of the overall bulge population must have evolved and died many millions of years ago. So where have these stars come from?

Rapid change in Galactic terms means 10,000 years - no changes are expected in our lifetime.

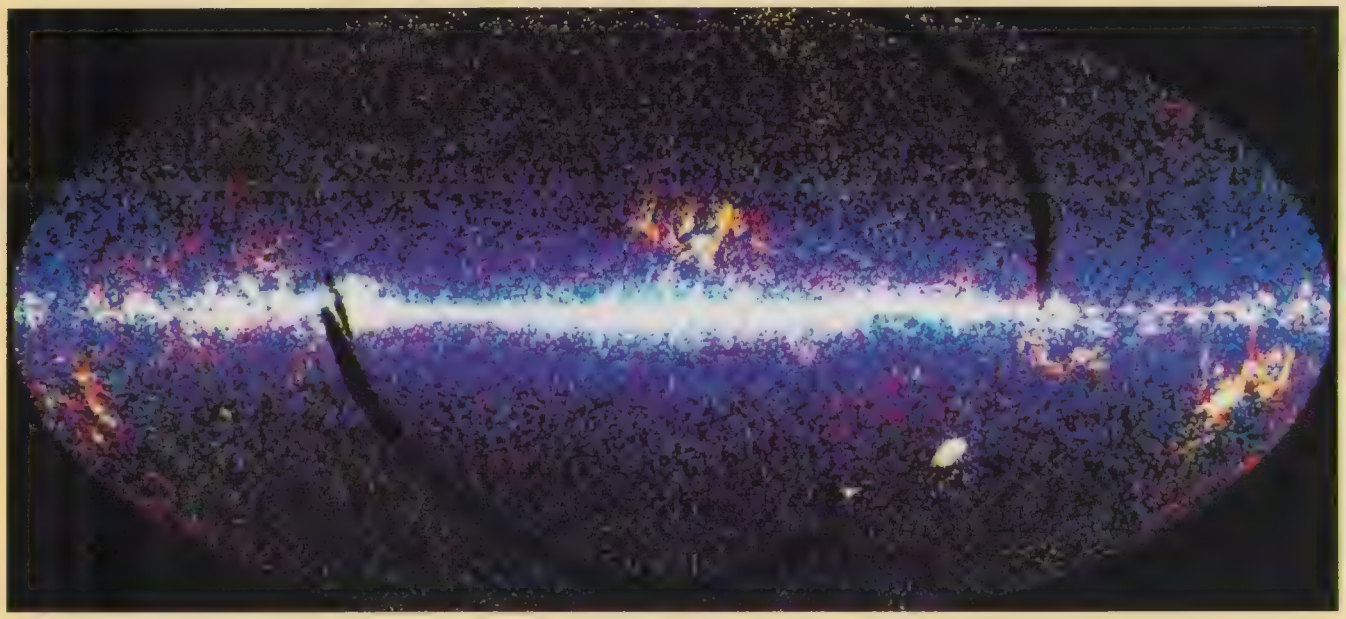
A further puzzle is that about twelve of these stars have unusual properties. They are thought to be related to the 'luminous blue variables' - O and B class stars that have finished the main part of their lives and have expanded to become blue supergiant stars. Only 20 of this type were known before the ones in the Galactic centre were discovered: ten each in the Large Magellanic Cloud galaxy and the main body of our Galaxy. To find so many in such a tiny region is remarkable and is believed to indicate that something unusual is going on. Possibly they hold the key to understanding the Galactic centre.

There are three competing theories about how the young stars in the very central cluster were created: ordinary star formation, merging stars and black holes with cloaks.

Stars are formed by condensing clouds of interstellar gas and dust. The problem with the idea of ordinary star formation at the Galactic centre, however, is that there doesn't appear to be enough gas at high enough density in the central cavity for new stars to be formed - the gas clouds are gravitationally disrupted before stars can condense out. One way around this is for star formation to occur every now and then, rather than continuously. The stars in the present cluster have strong 'stellar winds' which blow the gas out of the cavity, thereby preventing star formation. In a few million years these stars will die, exploding as supernovae.



The bizarre 'mini-spiral' feeding into the centre of the Galaxy. The 'arms' are thought to be streamers of gas torn from nearby gas clouds by the strong gravity of the galactic centre. (Image by N. Killeen and colleagues; courtesy NRAO/AUI.)



The Milky Way Galaxy

Our galaxy is an ordinary spiral galaxy, a circular disc of stars, gas and dust that rotates about its centre. In the middle of the disc is the bulge, which is about a tenth the radius of the disc but extends above and below it. Until recently the bulge was thought to be a sphere of gas and stars (with little dust, unlike the disc). However new, but still controversial, evidence suggests that the bulge is elongated in the shape of a 'bar'. If it is a bar it would feed gas down to the inner regions of the galaxy. A large portion of this gas is blown backwards before it can reach the centre, and only a tiny fraction makes it all the way to the very heart of the Milky Way. This heart lies 25 thousand light years from the Earth in the Sagittarius sector of the sky. *(Infrared whole-sky image courtesy JPL/IPAC.)*

Without their winds, gas could fall back in freely and 100,000 years later, if only one-hundredth of a solar mass falls in every year, there would be enough high density clumps for star formation to occur. The cycle would start again.

The second idea is that, in the past, large numbers of solar mass stars were formed. They would have been so thickly clustered that near-misses would have been frequent. Sometimes, instead of going into orbit about each other to form binary star systems, two stars would collide and merge to form one heavier star. If the stars collided and merged often enough, eventually some really massive, hot stars would have been created.

The final scenario involves black holes of about ten solar masses having close encounters with giant stars. The black holes would rip material from the stars and become enveloped in dense atmospheres. The atmospheres then would absorb the high energy radiation of the black holes and re-radiate it at lower wavelengths, in such a way as to mimic young, hot stars. However, the product of many of these black hole/stellar collisions would be binary systems. In these binaries, mass dumped from the star onto the black hole would produce copious quantities of X-rays, yet this type of X-ray sources is not seen in the Galactic centre.

The last two scenarios relied on the fact that the twelve unusual stars were thought to be unique to the centre of the Galaxy, and so an unusual creation mechanism was needed to explain them.

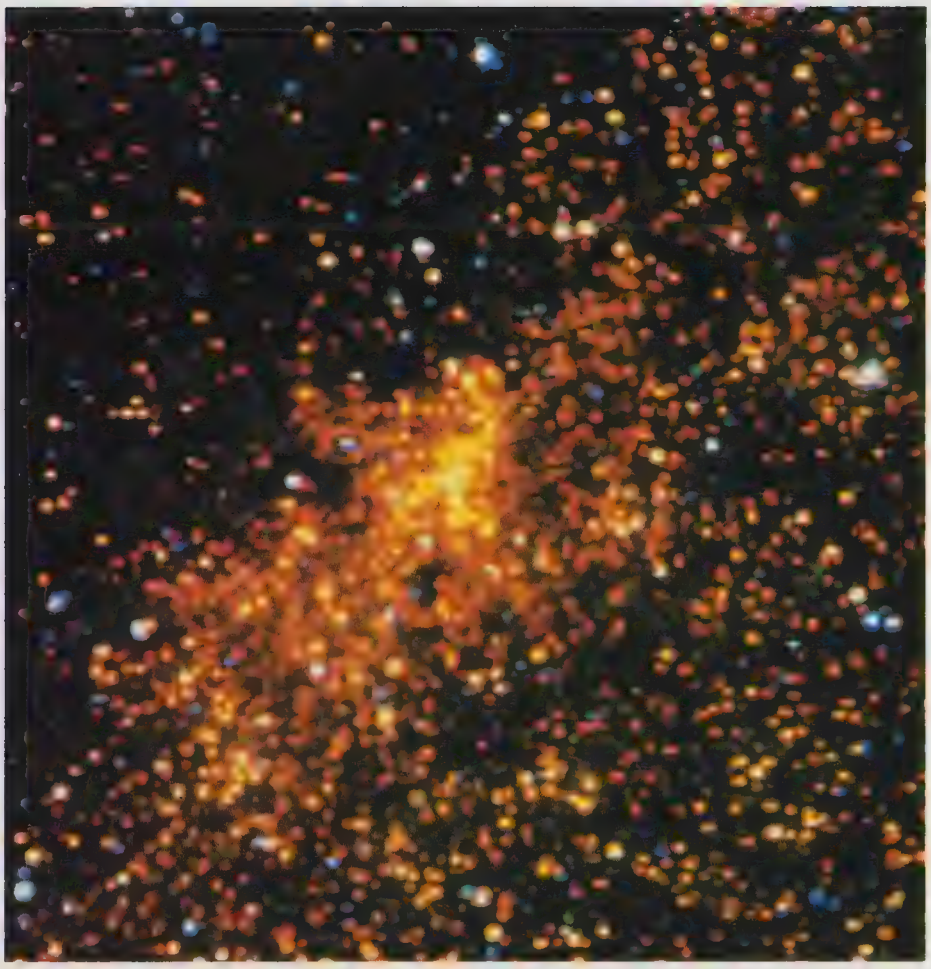
The tiny cluster of hot, young stars may hold the key to understanding the galactic centre.

However, stars like these have now been discovered only a few tens of light-years away from the central cluster, so an unusual mechanism is not so urgent anymore. The weight of evidence appears to be swinging towards episodic bursts of star formation to explain the inner stellar cluster.

The mysterious Sgr A*

The other unusual body within the central few light-years is the bright radio source Sgr A* (pronounced 'Sagittarius A star'). Just offset from the centre of the mini-spiral, this source has astronomers puzzled. It is smaller than ten times the distance from the Earth to the sun, it is not expanding and it is probably stationary. Observations show that the fastest it could be moving is 30 kilometres per second, and every time a new measurement is made it lowers the upper limit on this speed. Sgr A* has been tentatively spotted at infrared wavelengths, and there is some suggestion that it is not round but elongated.

The nuclei of some galaxies are so bright in the optical waveband that they outshine the rest of the galaxy. These active galactic nuclei (AGN) also produce copious quantities of X-rays and gamma rays. About ten percent of AGNs also produce radio emission. At radio wavelengths, Sgr A* looks very much like those AGNs, but at X-ray and gamma-ray energies it is somewhat pathetic. Indeed at the high energy end of the X-ray band, the source at the same position of Sgr A* is the weakest of the five sources within the central degree of the sky. However, because



An infrared image of the galactic centre, taken by David Allen and Michael Burton using the IRIS camera at the Anglo-Australian Telescope. The cluster of stars lies within the central light-year of the galaxy; dark patches are giant molecular clouds. (Courtesy AATB).

of the poor detail provided by X-ray and gamma-ray telescopes compared with radio telescopes, astronomers can't say whether all this high energy radiation comes from Sgr A* or some other source in the central region. Sgr A* may not radiate any X-ray or gamma-rays at all.

So what is this stationary, compact source, bright at radio frequencies and weak at higher energies? Its size suggests that it could be a binary radio star, a neutron star, a black hole or a young supernova remnant. The latter can be ruled out, as it is not expanding as young supernova remnants do. A neutron star, weighing in at only about 1.4 times the mass of our sun, should move through space much faster than Sgr A*, as only a very heavy object could sit so still in such a complex gravitational environment. Binary radio stars give intermittent outbursts of energy up to ten times the normal output of Sgr A*, and these outbursts have not been seen. This leaves only a black hole, or maybe something even more exotic that has not yet been thought of.

The discovery by Australian astronomers David Allen and Michael Burton, of a small group of hot stars (bottom of picture) only a short distance from the centre of the galaxy, leads astronomers to believe that small clusters of stars are born frequently in and around the galactic centre - an idea that was virtually unthinkable prior to this discovery.

If Sgr A* is a black hole then the elongated shape would be a disc of gas and dust surrounding it (an accretion disc). Radio waves would come either from material flowing onto the accretion disc and then spiralling ever inward, or from extremely energetic electrons being blasted out of the system in a jet of high energy. The low amount of high energy radiation can be accounted for in two ways: either the black hole is not very large, only a hundred solar masses, or it is a million solar-mass black hole accreting very slowly at present.

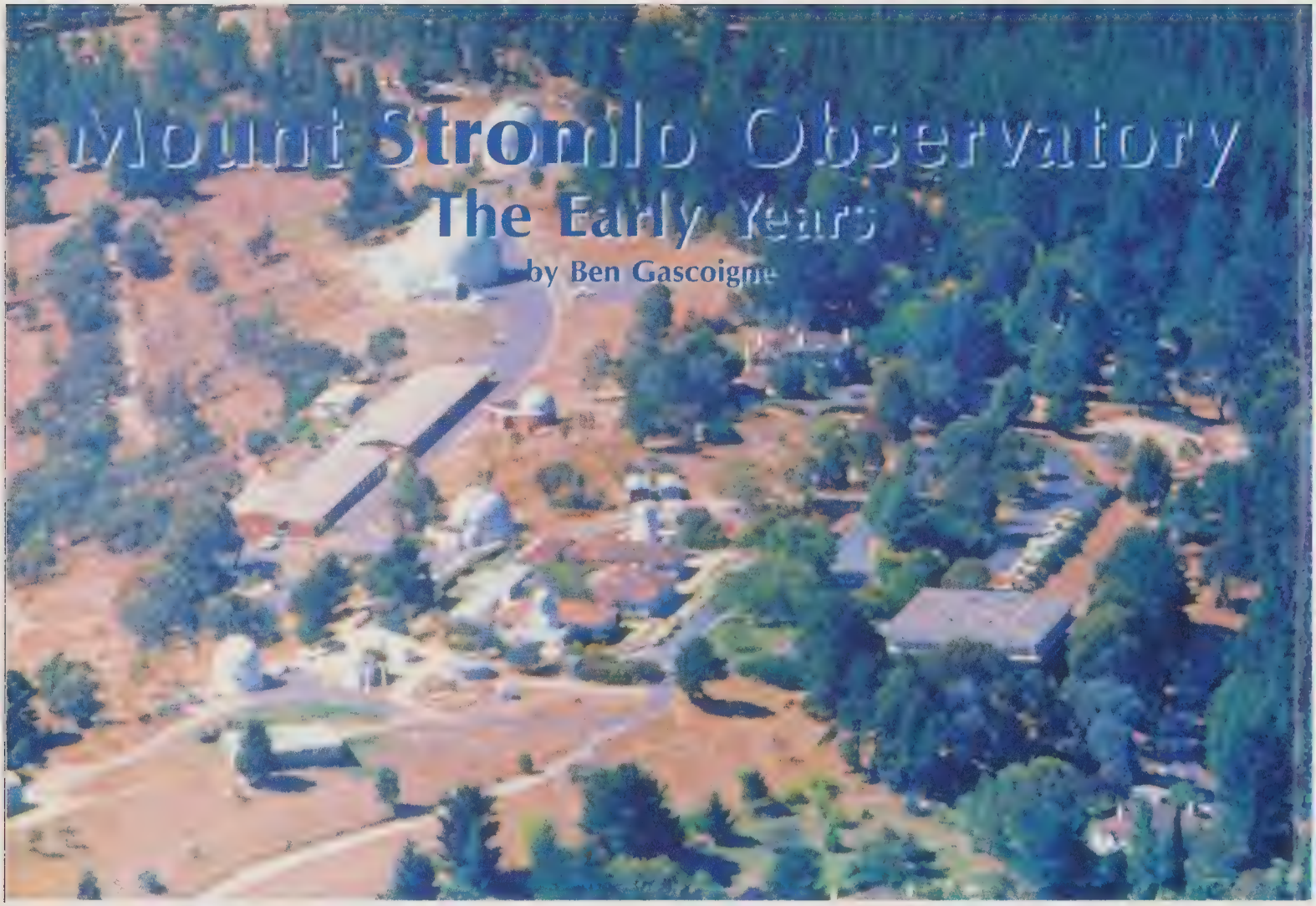
It is not easy to decide, given the present level of understanding, which of these ideas is correct. A clue may come from theoretical modelling of the motions of the molecular clouds and gas streamers in the circumnuclear disc and mini-spiral. These models seem to require a million solar-mass black hole in addition to the stars. If this is the case, the low accretion rate must be explained. Some astronomers argue that a black hole takes only one to ten years to swallow a star and produce large outbursts of energy, but that this happens fairly infrequently, which would appear to explain the observations. However, a Russian team have analysed data from their GRANAT X-ray satellite, and conclude that the Galactic centre has been quiescent for the last 400 years. This may be a serious challenge to the idea of black holes rapidly swallowing stars.

At present, the total luminosity of the Galactic centre can be accounted for solely by the hot, young stars in the inner core without invoking a massive black hole. On the other hand, the theoretical modelling of gas streamers suggests that a massive black hole is needed to explain the complex motions. If Sgr A* is a black hole, is it a high-mass or a low-mass black hole? And if it's a high-mass black hole, why is it quiescent? While great progress has been made in understanding the centre of the Milky Way, there is as yet no definite answer to the riddle in the middle. S&S

Dr Jenny Nicholls is a Research Fellow at the Research Centre for Theoretical Astrophysics at Sydney University. Her background is in the study of particle physics; her current research includes work on the Galactic centre and solar flares.

Mount Stromlo Observatory
The Early Years

by Ben Gascoigne



1994 marks the 70th anniversary of the birth of Mt Stromlo Observatory. In this first of two parts, Ben Gascoigne remembers the Observatory's early years . . .

The Observatory on Mount Stromlo owes its existence to the energy, foresight, and tenacity of one man, Walter Geoffrey Duffield (1879-1929). Born to a prominent South Australian family, Duffield broke early with the long-standing family commitment to financial and pastoral matters to pursue a career in science, a bold move at a time when scientific opportunities were strictly limited.

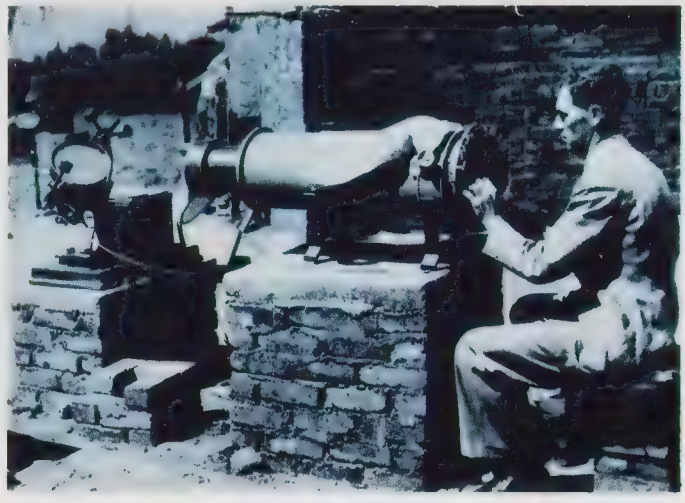
While still a graduate student in England he attended the 1905 meeting in Oxford of the International Union for Solar Research (the precursor of the International Astronomical Union) and it was there that he formulated the idea of an observatory in Australia. Among other reasons, it would fill a longitude gap between India and America in which no other solar observatory existed.

An expert publicist, Duffield enlisted wide support for his proposal, inside and outside Australia, and had gone so far as to have Mount Stromlo confirmed as a site, when the outbreak of war in 1914 prevented further progress. It was not until January 1924 that the Commonwealth Solar Observatory (CSO) officially came into being, with, naturally, Duffield as its first director.

Mount Stromlo had been suggested as a site by a governmental committee, and their choice was confirmed by tests carried out by astronomers from the Melbourne observatory. The tests were made with a fine 9-inch refractor presented to the embryo Observatory by James Oddie of Ballarat. The Oddie telescope remains in regular use, still housed in the first building erected by the Commonwealth in the ACT (in September 1911).

The Commonwealth Solar Observatory

The new Observatory settled down with a staff of about nine, five of them scientists. Their main activities centred about the study of the sun and the Earth's atmosphere. One of the principal instruments was a massive three-prism



Above: *Mt Stromlo Observatory from the air; the largest dome houses the 74-inch.* ***Right:*** *Cla Allen with a camera he and Arthur Higgs took to the 1940 solar eclipse in South Africa.*

spectrograph, fed by a vertical solar telescope with a ten-inch lens. With this spectrograph Cla Allen produced an extensive atlas of the sun's spectrum which became the Observatory's chief claim to fame; it played an important part in the formulation of the curve-of-growth technique, for many years the standard method of analysing stellar spectra.

Ron Giovanelli, later Chief of the CSIRO Division of Physics, studied solar eruptions and flares with a spectro-helioscope, so beginning a notable career in solar physics. The reflecting layers of the ionosphere, critically important to long-range radio communication in those pre-satellite days, were monitored by Arthur Higgs with radio-sounding equipment. Arthur Hogg, a chemist by training, worked on atmospheric electricity and then on cosmic rays. Finally, W.B. Rimmer, the only astronomer on the staff, studied southern stars from plates taken with the Oddie refractor. Unfortunately, the programme was cut short when he had a bad fall at the telescope in 1930.

Duffield had planned many of these activities, but because of his early death in 1929 he saw little of the outcome, still less of the extent to which the Observatory was to grow. Economic stringency delayed the appointment of his successor, and for the next ten years Rimmer acted as officer-in-charge. In 1937 the Government set up a small committee to decide on the future of the Observatory. For a while its fate must have hung in the balance, but the committee reported favourably, and Richard Woolley (later Sir Richard) duly became the next director.

Richard Woolley (left) with Sir Harold Spencer-Jones, the then Astronomer Royal, and Father Daniel O'Connell, of Riverview Observatory, Sydney. The time service slave clocks are in the background (Mt Stromlo was for many years responsible for the time service).

The Oddie telescope remains in regular use, still housed in the first building erected by the Commonwealth in the ACT.

Woolley arrived in December 1939, with the avowed purpose of discontinuing the Observatory's solar and geophysical work and directing its entire effort into stellar astronomy. His plans were disrupted by the outbreak of war, and within months the Observatory was making precision optical instruments for the military - sighting telescopes, artillery directors and the like. It became the only place in Australia where a complete telescope could be built under one roof, from initial layout to final assembly and testing. Eleven different instruments were so produced, either as prototypes or in small production runs, and the staff, predominantly locals from all walks of life, grew to a peak of over 70.

In retrospect, it seems incredible that such a miscellaneous group could have been trained to carry out such exacting work, but trained they were, the Observatory acquiring some invaluable skills along the way.

The Commonwealth Observatory

It was a very different Observatory that came out of the war. Its staff had tripled, and it had inherited large, well appointed workshops, with skilled and confident technical staffs. In its new guise it had the formidable task of finding a way into optical astronomy, one of the oldest and best established of the sciences, this with a staff on which stellar astrophysics was barely represented. Even Woolley's main observational experience, like Allen's, had been with the sun. It must be added that in Woolley's time, and before it, facilities for observational astrophysics in Britain were abysmal - he had had nowhere to learn.

The best telescope was a thirty-inch reflector donated by J.H. Reynolds in 1924. Erected in 1933, it was the largest in the country, but had never been used - by 1933 the staff had all developed their own lines of work and were not interested. The Observatory had also acquired, as scrap, the old Great Melbourne Telescope (the GMT) with its notorious 48-inch speculum mirror.

In 1947, Woolley successfully approached the Government for a 74-inch reflector, similar to one being built for Pretoria. It went into action in 1956 as one of the larger telescopes of its time, a tremendous step forward. All the earlier telescopes had to be overhauled and modernised (especially the GMT), and instruments of all sorts built for them. It took time, and it was not until the early 1950s that Stromlo began to publish significant scientific papers. Meanwhile the CSIRO Radiophysics people were making their world-shattering discoveries, almost every month it seemed, and the Stromlo staff could only admire them from a distance, grind their teeth, and swear that one day they would too.

Nevertheless, and for all their inexperience, they opened up lines of work which produced results quite early and have been followed up ever since. A typical example is that of Colin Gum, one of the first graduate students. Using a makeshift camera (the original, designed by Cla Allen, had been seriously damaged in the fire of February 5, 1952), he carried out a survey of the Southern Milky Way, in the course of which he found 40 new nebulae, including the famous one in Vela which now bears his name. And having determined distances to stars rather after Rimmer's style, he was able to delineate the southern extension of the galactic spiral arm just discovered by Morgan in the north. This was a major contribution.

A few years later the Gum survey was repeated by Rodgers, Campbell and Whiteoak, with a better camera and covering a wider belt of sky. Then Don Faulkner and Lawrence Aller carried out a more physically-orientated study of the 30 Doradus and Eta Carina nebulae, using a photoelectric spectrum scanner which Aller, a visiting American, had brought with him. They were followed by Rodgers and Searle and, interest now shifting to supernovae remnants, Mathewson, whose group combined optical and radio observations with great effect, and currently Mike Dopita, whose widely recognised work continues to this day. This kind of continuity, extending over many years and involving people with many differing approaches and points of view, has been a continuing source of strength to Mount Stromlo.

I had joined the staff in 1941 with what at that particular time could hardly have been a better recommendation, a part-PhD in astronomical optics. I stayed on after the war, and by 1950 had

decided to study a particular type of variable star (cepheids) in the Magellanic Cloud galaxies, with the Cloud star clusters as a second string. Just at the right time the American astronomer Gerry Kron arrived on an extended visit. He was accompanied by Olin Eggen, of whom more later, and by the best photoelectric photometers (electronic light detectors) in the business - he was the acknowledged expert in this almost exclusively American field.

Gerry's photometer, the first of its type I had ever encountered, was exactly the tool I wanted, and all my good luck had come at the one time. We teamed up, were given nine months solid on the Reynolds, got some most exciting results, and I was hooked for life. Cepheid variables, or more generally pulsating variables, became one of the Observatory's big subjects. Alex Rodgers was next, entering into the field from quite a different direction, and he was followed with hardly a break by a long series of others, each contributing something new and distinctive.

A third new line was established by Gerard de Vaucouleurs with his atlas of southern galaxies, made from photographs taken with the Reynolds of the 210 most prominent galaxies south of -35° declination. It was to carry out such a programme that Reynolds had presented the telescope in the first place, and especially in de Vaucouleurs' capable hands, it gave extragalactic astronomy a good start at the Observatory.

I mentioned the 1952 fire only briefly. It was a bad season for bushfires, and a man had been killed in one near Stromlo only a few days before. Ours was started by a lightning strike on a hill a couple of miles to the north-west. We thought it would pass to our west, but just at the wrong time the wind changed and blew up into a gale, and it was clear we were for it. The Observatory was in the middle of extensive pine plantations, with a million or so pine trees that went up in a couple of hours. At the height of the fire the sky was bright orange, full of flying embers and pine resin, and its roar was like the roar of the surf on a really heavy day.

Only one substantial building - the workshop - was lost, which being impregnated with grease and oil burned furiously. The climax was marked with a tremendous explosion, and a burst oxygen cylinder came flying out through the wall, its inch-thick steel plate peeled back like a half-skinned banana.

Ben Gascoigne with the transit telescope built for the time service. Mt Stromlo became responsible for the service when Melbourne Observatory closed in 1944.

Workshop foreman Jim Banham surveys the burned-out wreckage after the 1952 fire. The site is now the drawing office and tea room.

Returning to Woolley, his best work was by way of a farewell to the sun, a celebrated review of the physics of the solar corona he wrote in collaboration with Allen. On the whole, he let his staff pursue their own researches in their own way. His achievements were concerned more with organisational and political matters, which is not to diminish their importance in any way. I have mentioned the general build-up of telescope power, especially the 74-inch (the GMT had yet to come on stream), and of technical resources. He also established the graduate school which flowered to such an extent under Bok, becoming one of the major features of the Observatory, and indeed of Australian astronomy.

Just before he left, to become the eleventh Astronomer Royal and Director of the Royal Greenwich Observatory, Woolley had the Observatory transferred from the Department of the Interior to the Australian National University, which for the predominantly research institute it had become, was a change of great significance.

Bok instituted the search for a darker site, leading to the choice of Siding Spring. For this alone he deserves the lasting gratitude of Australian astronomers.

The Mount Stromlo Observatory

Woolley left in 1955, and Bart Bok, his exuberant and irrepressible successor, arrived in 1957. Bok was born in Holland in 1906, proceeded to Harvard in 1929 and remained there for the next 28 years, becoming widely known first for his work in galactic structure, then as a pioneer of radio astronomy in the USA. I have written of Bok and Woolley: *'They were men of widely different character and temperament who detested each other. Once or twice I was left with the two of them, making uneasy conversation to each in turn while they declined to exchange a word.'* Perhaps it was because of this that Bok was able

Left: *Bart Bok, director from 1957 to 1966.*
Below: *The 74-inch (1.9-metre) telescope photographed in 1978 before the construction of a fully enclosed control room.*

to complete so well what Woolley had begun, not of course without leaving his own unmistakable stamp on whatever he did.

He saw early how seriously the Mt Stromlo night sky was threatened by the encroachment of Canberra, and instituted the search for a darker, better site. This search covered wide areas of the country and led to the choice of Siding Spring. For this alone he deserves the lasting gratitude of Australian astronomers. He was a great builder: the Observatory owes to him the Duffield Building, the photographic and electronics laboratories, the Siding Spring complex, and the 40-inch telescope, the first really modern telescope the Observatory had ever had (the 74-inch was built too soon after the War to incorporate any wartime technology). The spectrograph for the 74-inch, built by T.E. Dunham of Mount Wilson (California) fame, made great areas of stellar and interstellar astrophysics accessible to the staff for the first time. Bok was an incomparable publicist, and through his innumerable addresses, at Parliament House, Meekatharra primary school, and everywhere in between, he implanted astronomy firmly within the Australian consciousness.

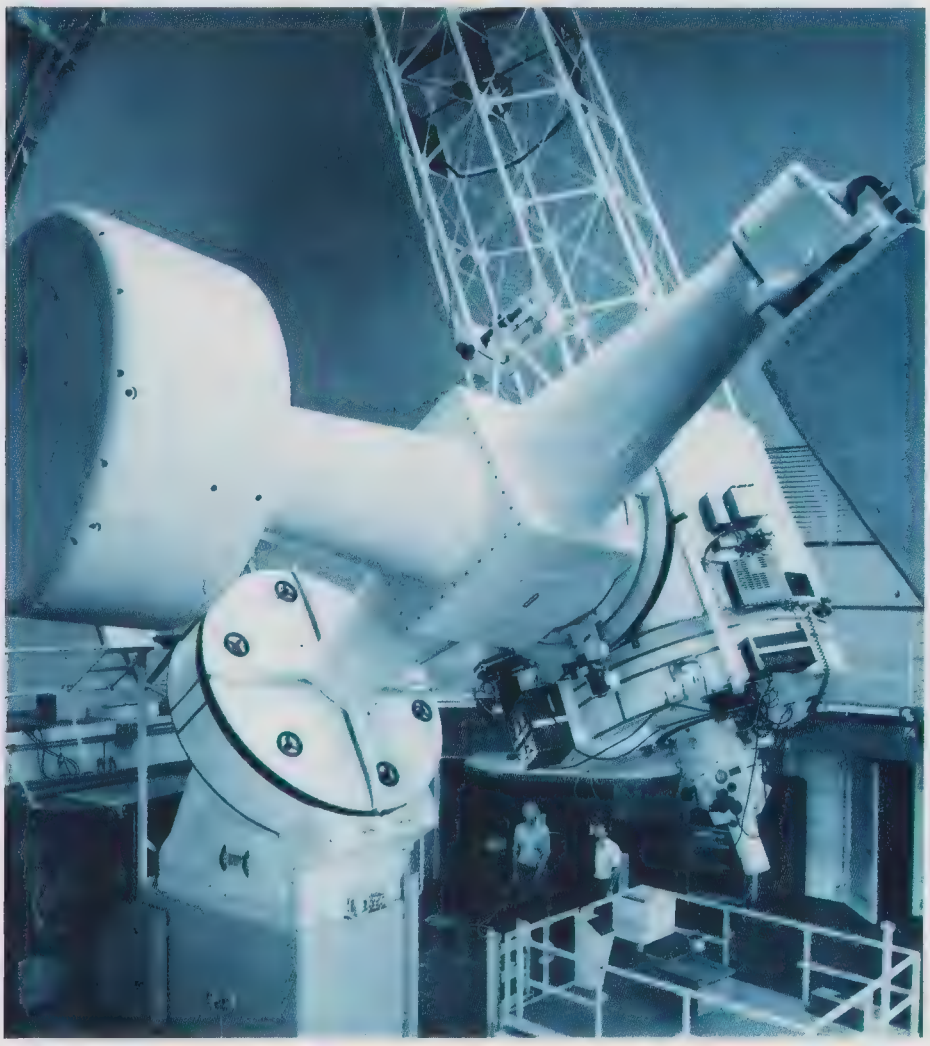
He also established close relations with the CSIRO Radiophysics Division in Sydney. Not long before he left we had a colloquium at Mt Stromlo, held jointly with Radiophysics, on problems of mutual interest with contributions from both sides. I well remember how, during the first coffee break, Leonard Searle (now Director of Mount Wilson) came up to me and said 'Ben, I think we're ahead on points'. I thought so too, and it was a great day. We had caught up with them at last.

I have mentioned the importance of the graduate school. This was undoubtedly Bok's pride and joy, and he and his wife Priscilla poured themselves into it without stint. It changed the character of the Observatory. Many of the research programmes came to centre around the graduate students, and they in turn were treated almost as full staff members, with much the same degree of access to the best instruments and equipment.

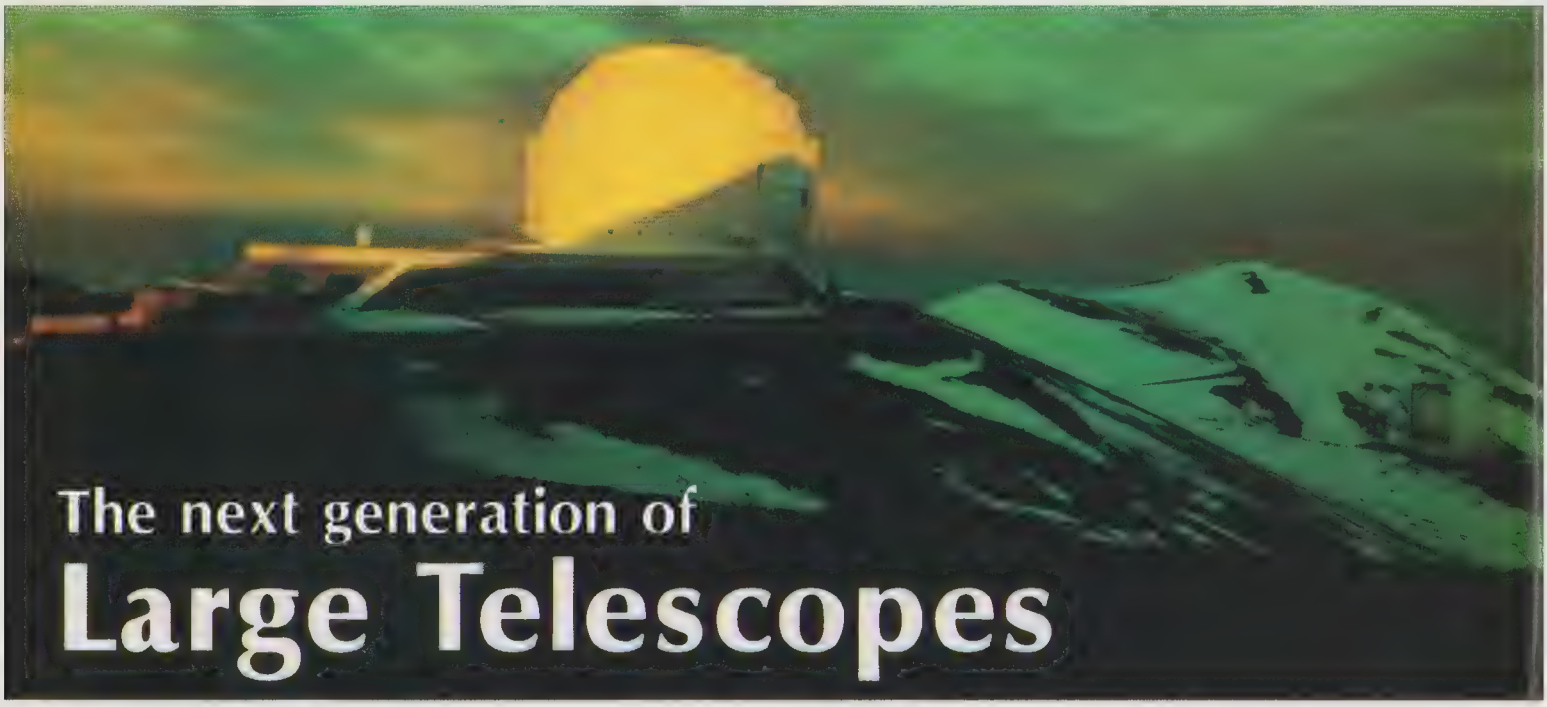
It paid handsomely. A number of those students are now full-scale directors, including Ron Ekers (Australia Telescope National Facility, CSIRO), Jeremy Mould (Mount Stromlo), and Marc Price (Parkes), and I always saw the graduate school as the one great advantage which we had and Radiophysics didn't have. Another of Bok's assets, one which had been denied Woolley, was 'his intimate knowledge of the American astronomical scene, together with the innumerable personal contacts he had accumulated during his 28 years in the USA'.

This review of Mount Stromlo's early years would not be complete without an acknowledgment of the debt the Observatory owes to four visitors from the USA, all of whom introduced us to instruments and observing techniques without which our progress would have been considerably slower. These four were Gerry Kron, with his photoelectric photometry; Laurence Aller, whose spectrum scanner, and following it the one we built ourselves, was used by a whole generation; Ted Dunham, whose superb spectrograph at the 74-inch has been an enduring tower of strength; and Kent Ford, who in 1970 brought with him the first image intensifier most of us had seen.

By the end of Bok's term the Observatory had settled into the form and character it still possesses. He left it in good shape, with a solid international reputation and a future that seemed full of promise. S&S



Dr Ben Gascoigne worked on military optics at Mt Stromlo during World War II before joining the staff. He was advisor to the AAT Project from 1967-74, and Commissioning Astronomer from 1974-75. He is co-author of The Creation of the Anglo-Australian Telescope *published by Cambridge Uni. Press.*



The next generation of Large Telescopes

A new generation of giant telescopes soon will be coming on-line around the world. Will Australia be able to keep up? Malcolm Miller reports . . .

The goal of a large optical and infrared telescope, according to Dr Jeremy Mould, Director of Mount Stromlo and Siding Spring Observatories, 'is to make discoveries which we couldn't make with a 4-metre telescope'. This statement set the agenda for a possibly seminal workshop on Large Optical/Infrared Telescopes held at Mount Stromlo Observatory on February 7. About sixty astronomers attended the workshop, representing the major observatories and universities.

Australia's current position in world astronomy is good, largely because of the instruments that have been developed for use with our telescopes. 'We had the best, though not the first, of the 4-metre telescopes,' Dr Mould pointed out. But the era of 8- to 10-metre optical telescopes was now here, and this was the challenge in which we, as a nation, must participate or lose our world status.

To show us what we were up against in our desire to keep up, Professor Massimo Tarenghi of the European Southern Observatory (ESO) gave a talk on the ESO Very Large Telescope (VLT) project, which left participants stunned by its magnitude. (Prof Tarenghi is the VLT Programme Manager.)

The VLT will comprise four separate telescopes on the same site, each feeding starlight into a common laboratory. In addition, a number of smaller telescopes will be connected to the laboratories to utilise equipment unused from time to time by the larger telescopes. The main telescopes will have active optics systems (ie. making tiny changes to the shape of the mirror to overcome the blurring effect of the atmosphere), 8.2-metre primary mirrors, and 'flushed' enclosures - ventilated straight-sided buildings in which a wind-tunnel tested combination of louvres, fans, windshield, and underneath spaces reduces dome turbulence to a minimum.

ESO has been able to demonstrate that thin primary mirrors when combined with active optics can give the best dollar per aperture ratio. The active optics control also overcomes tiny manufacturing defects and corrects for errors in the telescope guiding system.

Although the mirrors are 8.2 metres in diameter, they are only 175mm thick and weigh a mere 23 tonnes! Made of Zerodur ceramic by Schott Glassworks at Mainz, Germany, they are spun while cooling to generate an initial surface curve so accurate that no more than 1.5mm of glass needs to be removed during polishing! When poured, the glass radiates 29 megawatts of heat before a reflective cover is lowered to the control cooling rate.

The secondary mirrors will be made either of silicon carbide or beryllium (glass would be too heavy). Although the diameter of these mirrors is more than a metre, they will weigh only 30 kilogrammes!

The telescope motor drive mechanisms will not use anything as crude as gears. Instead, a monster electric motor, nine metres in diameter will drive the telescope directly. Laser beams will be used to keep track of the telescope's position.

Each telescope will be erected first in the factory for tests, then dismantled for transport and erection at the prepared site at Paranal, Chile, on the edge of the Atacama Desert. Paranal is only 12 kilometres from the Pacific, at an altitude of 2,664 metres. Once construction is complete, no one will walk about between the domes - the buildings will be connected by underground walkways and tunnels. Workshops and residential quarters will be some distance away, out of sight from the mountain top.

The total cost of the VLT will be around $500 million - comparable with the cost of repairing the Hubble Space Telescope, a sum which Australia could never hope to afford. Funding comes from eight European countries with enormous resources in manufacturing, engineering design, and population. The whole instrument will be the equivalent to one

A computer-generated cut-away sketch of one of Europe's new VLT telescopes, due to come on-line around the turn of the century.

16-metre telescope, and so will be very competitive with the twin Keck telescopes on Hawaii, and ahead of the Gemini telescopes.

At this stage of the workshop, people were already wondering whether Australia's astronomical future lies in 'niche astronomy' rather than frontline competition with the 'big boys'. Niche astronomy means concentrating on a few things which we do as well as or better than the rest of the world, and involves a conscious decision to leave the front rank forever, with all that would mean for our PhD students and probably for the status - and funding - of astronomy in this country.

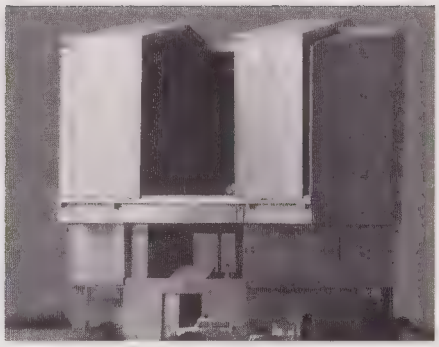
An Australian option

Professor Alex Rodgers is a veteran Stromlo astronomer who has been an advocate of a large telescope for Australia since 1986. Not one to go for half measures, his preference is for a 14-metre instrument to be set up in Australia and largely built here. His earlier designs proposed a mirror made of segments (like Keck), but recent work with thin mirrors confirms that both technologies work. One very important difference is that mirror segments are easier and cheaper to make, transport, and handle than enormous single mirrors. The cost of a re-aluminising facility becomes a substantial amount for these glass giants.

The future of optical astronomy in Australia depends on innovative, state-of-the-art work done by Australians.

Another advantage of the segmented mirror is that the number of segments, and thus the overall design, can be trimmed to various time and budget constraints, and of course the queue for getting the mirror blanks is much shorter.

It's no good having a giant telescope unless you have suitable site on which to put it. This means good seeing (ie. a low incidence of atmospheric turbulence) and sparse cloud cover. The best place found so far in Australia is Mount Freeling, in the Flinders Ranges, which promises average seeing of about 1.2 arcseconds - not up to the standard of Chile or Hawaii. The number of clear nights is about the same, but high temperatures offset the advantage of the desert's low water vapour (important for infrared astronomy).



Above: *One of the giant VLT mirror blanks - 8.2m in diameter, but only 175mm thick.*
Right: *Artist's impression of a VLT enclosure - they're not called domes anymore.*

Australia's present level of collaboration with astronomers from elsewhere is based on the quality of our astronomers and our specialist engineers. Without these we would not have the amount of time we do have on the Hubble Telescope and other major instruments belonging to others. The future of optical/infrared astronomy in Australia depends on the continued worth of our collaboration, which in turn depends on innovative, state-of-the-art work done by Australians.

The alternatives to a large telescope in Australia involve going offshore, most likely to either Chile or Hawaii. Financial constraints mean that we need overseas partners to build large new facilities, but Prof. Rodgers could not suggest who these might be. His belief is that our minimum option is a Keck-style 10-metre telescope.

Commenting on this talk, Professor Mould proposed another option - a telescope for spectrographic work only (analysing the spectrum of starlight, rather than taking images. Ed.) which could be made for less expense and which would not need the best seeing conditions.

The Chief Project Scientist for The Magellan Project, Dr Steve Shectman, then told us about a rather more affordable telescope being built for the Carnegie Institute of Washington (CIW) and the University of Arizona. Its name should not be confused with the highly successful Venus probe!

Just one week before the Workshop, the first Magellan 6.5-metre diameter mirror had been spin-cast at the optical workshops of the University of Arizona. The telescope is to be sited near Las Campanas in Chile, on a site further inland from other telescopes at Las Campanas and a bit windier, but with better seeing. The effect of wind has been minimised, as is current practice, by mechanical design features of the enclosure - they aren't called 'domes' any more.

The Magellan telescope's tube has the mirror and its holding cell built-in as a structural element. The upper part of the tube is extremely light - it doesn't even need strengthening struts. Instruments are mounted on 'rotator flanges' which hover independently just above the mirror, removing most sources of flexure between optics and instruments. The telescope enclosure is open underneath to help control air flow.

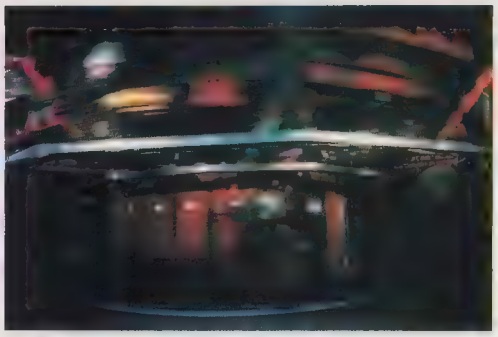
The Magellan Project is well advanced. It will share the facilities already at Las Campanas, and cost between $US30 million and $US40 million.

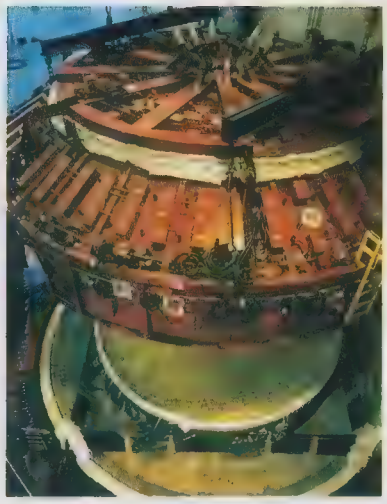
A new 'scope for Siding Spring?

The next presentation was from Professor Don Mathewson (Mt Stromlo), who proposed a carbon copy of the Magellan telescope for Siding Spring Observatory in NSW. It appears that the Magellan people are sympathetic to our cause and would probably be willing to make available free, millions of dollars of valuable design information.

Professor Mathewson feels that the upgrading of Siding Spring which would result would be sufficient to ensure the

Professor Alex Rodgers next to a model of his proposed 14-metre telescope.





Making a molten mirror - clockwise from top left: glass blocks are placed into a pre-shaped furnace mould; the huge electric furnace is lowered; the whole apparatus spins to create a curve on the mirror's surface (photos by Lori Stiles/Uni. of Arizona). ***Below:*** *Building the first Keck telescope (Courtesy CARA).*

continued partnership between Australian astronomers and those from other parts of the world.

Showing that he'd done his homework, he suggested a tight schedule for his proposal, starting with a decision from astronomers within a few days and ending with a grand opening of the telescope in time for the beginning of the Olympic Games in 2000!

'It's really the engineers that make possible all the goodies astronomers get,' Mathewson said, and engineering aspects and solutions certainly loomed large throughout this workshop.

While an aluminising plant for a 6.5-metre mirror would have to built especially for this instrument at Siding Spring, this would be partly offset by the construction of an auxiliary optical 'feed' to the existing 3.9-metre Anglo-Australian Telescope (AAT) so that some instruments could be shared between the two. Improved dome ventilation would provide better seeing than is currently achieved with the AAT. A preliminary analysis by John Hunt (the Mt Stromlo engineer who led the team which designed the innovative 2.3-metre telescope at Siding Spring), indicates a cost of $31 million. Two thirds of the telescope could be built in Australia.

A break in the proceedings gave an opportunity for fierce discussion between the supporters of different projects, and of course those who felt we should seek to join overseas efforts. The political considerations of what is, for Australia, 'Big Science' must be kept in mind, and participants were reminded of the importance of unanimity in the astronomical community when new telescopes are proposed. One rather unpalatable, but perhaps necessary question raised was: 'What old facilities would have to be closed down to make new ones possible?' This sent shivers down spines, since nobody ever wants to close down working telescopes, yet this may become a necessary trade-off.

Dr Don Morton, a former Director of the Anglo-Australian Observatory (now working in Canada), brought us up to date on the Gemini Project. Only last year, Australian astronomers decided they would not ask the Federal Government for money to buy a share in that twin 8-metre telescope project. The present shareholders are: USA 50%, UK 25%, Canada 15%, Chile 5%, Argentina 2.5%, and Brazil 2.5%.

The Gemini mirrors will be only 20cm thick, using what now seems to be the normal thin mirror technology. The cost will be around $US176 million. The first one will be placed on Mauna Kea, Hawaii, and the second at Cerro Pachon, near Cerro Tololo in Chile. The dome will be vented but of conventional shape, with the aluminizing plant inside.

The final Workshop session included an outline, by Professor Tarenghi, of what it would cost Australia to become a full partner in the ESO, with implied access to all of the telescopes there, including the VLT. Our share of the annual budget would be 4.37%. He calculated this as $5 million in 1993. In addition, there would be a once-only entrance fee of $8-16 million. This would be our contribution to all development costs prior to joining. Being a member wouldn't give us any quota of time allocation, since this is based only on the scientific merit of the proposals. But it would cover all travel costs as well as use of all facilities for data reduction. We would be able to tender for supply of instrumentation as long as we were competitive (and we are in some fields!).

The next step is for a national committee on astronomy to consider all the ideas, and make a proposal to government later this year. The outcome of that process will be a vital indicator for the future direction of Australian astronomy. S&S

Malcolm Miller is a Canberra-based journalist, and a former Mt Stromlo astronomer. Several of his articles have appeared in SKY & SPACE; he also writes for the CSIRO Helix magazine.

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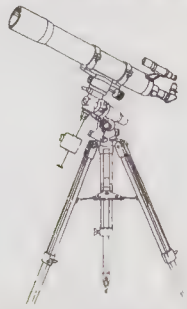

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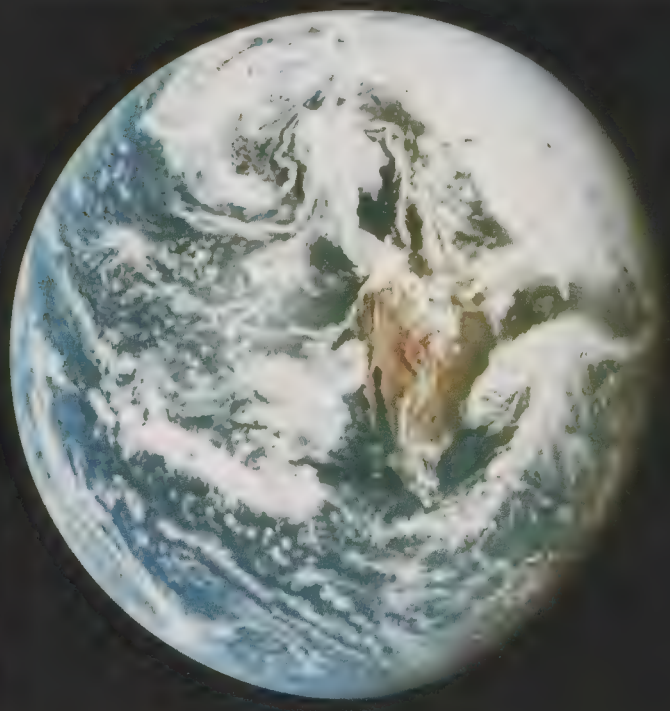
The Final Countdown

by Kerrie Dougherty



In this final installment before the 'big one' - the Apollo 11 Moon landing - Kerrie Dougherty takes a look back at the Apollo 9 and 10 spaceflights, the final dress rehearsals for the Moon landing itself.

Following the successful Apollo 8 mission in December, 1968, NASA pressed forward with its Moon landing programme, confident at last that it was on track to achieve President Kennedy's goal before the end of 1969. However, before the lunar landing itself could actually take place, the Lunar Module, the vehicle specially designed to land the astronauts on the lunar surface, had to be flight tested.

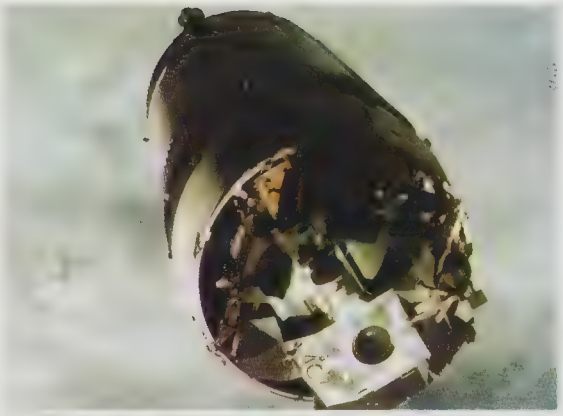
Apollo 8 had originally been slated as the mission to test the Lunar Module in Earth orbit. However, developmental delays with the spacecraft meant that it was not ready for flight at the time when NASA decided to send Apollo 8 on a lunar orbit mission in order to beat the Soviet Union to the achievement of putting the first people in lunar orbit. It would be left to the next mission, Apollo 9, to put the landing spacecraft through its paces.

The Lunar Module (LM) was a complex craft, the first space vehicle ever designed exclusively to function outside the Earth's atmosphere and gravity. Unlike the Apollo Command Module (CM), the LM would never have to face the severe stresses of re-entry and would only have to contend with the gentler one-sixth gravity conditions of the Moon, during its operational use. However, it had to be designed to tight weight and size tolerances, in order to be accommodated on the Saturn 5 rocket, yet still be robust enough to carry its own rocket engines for landing and take-off from the Moon. Because the Lunar Module was the astronauts' only way onto and off the Moon, its designers and engineers had to be certain that it would operate flawlessly: there could be no hope of rescue for astronauts stranded on the Moon if the LM failed.

Consequently, the spacecraft proved difficult to design and its orbital test flight was continually delayed, until it reached a point in early 1969, where it was feared that further delay would compromise the already established July date for the lunar landing. Finally, in February 1969, the LM was ready for flight, but even then the test mission was postponed for two days, when the crew developed minor colds. (The earlier Apollo 7 mission had shown that crews with colds in space did not function at their best!).

On March 4, Apollo 9 finally lifted off, carrying with it the spider-shaped Lunar Module. The crew consisted of Commander James McDivitt, Command Module Pilot David Scott and Lunar Module Pilot Russell ('Rusty') Schweickart. As this was the first flight in which mission controllers would have to communicate with two spacecraft both carrying the same mission designation,

Above: *Apollo 10 view of the Earth from 58,000 kilometres.*
Right: *The Apollo 9 crew - James McDivitt, David Scott and Russell Schweickart.*



Left: *The Apollo 9 lunar module 'Spider', still attached to the Saturn V third stage, waiting to be extracted by the command module 'Gumdrop'.*

Right: *'Spider' flies free near the Apollo 9 command module. This was the first manned flight of the lunar module in Earth orbit.*

it was decided to give the spacecraft individual names, which were chosen by the astronauts. It was the first time since the Mercury missions (1961-63) that spacecraft had been given individual names, apart from the 'unofficial' Gemini 3 name of Molly Brown. The Apollo 9 crew named their Command Module Gumdrop, as its shape resembled that popular sweet, and appropriately chose Spider for the Lunar Module.

The 10-day Earth orbit mission was designed to give the Lunar Module a thorough shakedown in order to manrate the design for a lunar flight. Three hours after launch, Gumdrop pulled away from the final stage of the Saturn 5, in order to perform the docking manoeuvre with the Lunar Module, which was stowed below the Command Module during take off. The CM turned around and then nosed back in to the docking port of the LM, making use of the docking techniques perfected during the Gemini and Apollo 7 flights. Head-to-head, the docking bond between the two spacecraft was tested by firing the powerful engines of the Command-Service Module at various angles. The schedule for the first five days of the mission was a heavy one, testing the various systems of the LM, as well as spacewalks to test the portable life support system intended for use on the Moon.

Three days into the flight, Schweickart and McDivitt crawled through the docking tunnel into the Spider, in order to ready it for flight. They checked its electrical system and computer, extended its landing legs and test fired its descent engine (the engine that would be used to cushion the astronauts' landing on the Moon). The following day, with Scott in the CM and Schweickart and McDivitt in the LM, the two craft were separated. When they were 182km apart, with Spider in an orbit of its own, six hours of tests began. First the descent to the lunar surface was simulated. Then the descent stage was jettisoned and the ascent stage engine was fired to simulate the lift off from the Moon. The tests concluded with a simulated lunar take off and rendezvous with the Command Module.

Following these tests, the last five days of the mission had a comparatively light workload, with the crew concentrating on landmark tracking and experiments in Earth photography, as well as conducting additional tests on the CM. The LM Spider was jettisoned shortly before re-entry and remained in orbit until October 26, 1981, when it was finally destroyed on re-entry. The Apollo 9 splashdown, on March 14, 1969, saw the first live telecast of a spacecraft landing and recovery.

The Apollo 9 mission had certified the Lunar Module as spaceworthy. Now everything was ready for a final test flight to the Moon of the entire Apollo system. The Apollo 10 mission was planned to be a full-scale dress rehearsal for Apollo 11, reassuring NASA (and its political masters), that the Moon landing mission, with all its propaganda significance, had every chance of success.

During the Apollo 9 and 10 missions, NASA's Australian tracking stations played their part in maintaining communications with the spacecraft. During those periods when both the CM and

Floating in space

Interview by Carol Oliver

Once in Earth orbit, astronauts Rusty Schweickart and Jim McDivitt climbed into the 'Spider' lunar module and undocked from 'Gumdrop'. It was an almost flawless exercise with the two spacecraft separating by 182 kilometres and then redocking. The spacewalking was a success too, although Schwieckart reveals it wasn't without incident.

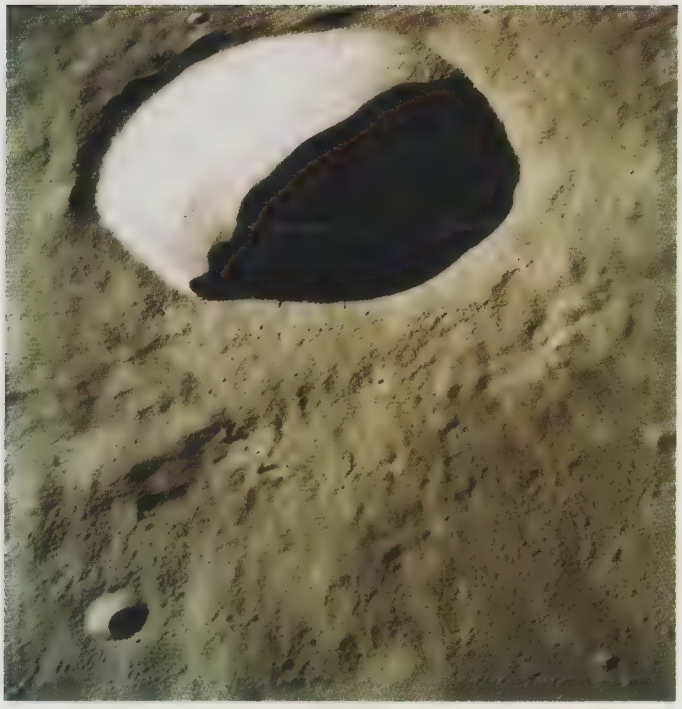
Schwieckart floating in space.

Early in his spacewalk, Schwieckart discovered that the camera he was supposed to use had jammed. At that point his feet were out of the 'golden slippers' on the spacecraft and he was hanging onto the handrail with his hands. It was decided the other two astronauts would try to fix the camera while Schwieckart held his position, an experience that would change forever his outlook.

'There I was in space with nothing to do for five minutes, except just hang there with one hand on the handrail of a spacecraft travelling at 17,000 miles per hour and look at our incredibly beautiful planet. Nobody was yakking or talking to me ... it was completely silent. I realised very rapidly that this was the opportunity to really look ... it changed a lot of my life afterwards.'

The silence of the spacesuit and its feel came as a pleasant surprise to Schwieckart. On Earth the suit had been a cumbersome and weighty balloon. 'You end up with marks all over your body to the point where sometimes you're literally bleeding by the time you get through the simulations,' said Schwieckart. 'And then you get into space and you don't even feel it. It's not just that it's weightless ... you're floating inside it, you're not even touching it. It's a completely different experience.'

Carol Oliver is a freelance space writer and interviewer.



***Left:** Apollo 10 view of the crater Schmidt on the edge of the Sea of Tranquility. **Above:** 'Snoopy' ascends from lunar orbit to re-dock with 'Charlie Brown'. **Below left:** Apollo 10 crew - Eugene Cernan, John Young and Thomas Stafford.*

LM were manoeuvreing, the Manned Space Flight Network station at Honeysuckle Creek, south of Canberra (built specifically for the Apollo programme), was used to maintain contact with the Lunar Module, while the Deep Space Network tracking station at Tidbinbilla, provided communications links for the Command Module.

For the Apollo 10 mission, the Command Module was named Charlie Brown and the Lunar Module was called Snoopy, the crew being fans of the famous Peanuts comic strip. Surprisingly, the choice caused some public controversy, with NASA being accused of 'trivialising' the space programme! The crew was Commander Thomas Stafford, Command Module Pilot John Young and Lunar Module Pilot Eugene Cernan. The latter two would later return to the Moon on the Apollo 16 and 17 missions respectively, thus becoming the only astronauts to make two trips to lunar orbit.

Apollo 10 lifted off on May 19, every moment of the flight planned to closely duplicate that of Apollo 11. Once safely on the way to the Moon, the crew performed the docking manouevre with the Lunar Module, providing the opportunity for the first live colour television broadcasts from space. Cernan televised the approach to the LM and, two hours later, treated a US prime time viewing audience to spectacular live views of the Earth from space.

The voyage to the Moon was uneventful and routine, and NASA made the most of its colour broadcast technology by scheduling a number of live transmissions from space, which the astronauts 'hammed up' considerably. Only once did they step outside the 'script', complaining of their dislike for the chlorinated drinking water!

The serious part of the mission began once the spacecraft were in lunar orbit. After the first colour broadcasts of the lunar surface, on the third orbit, the crew began their preparations for a simulation of the Apollo 11 landing. Undocking from Charlie Brown, Stafford and Cernan took Snoopy out of lunar orbit and descended towards the Moon, along the same path that Apollo 11's LM Eagle was to take less than two months later. They took their spacecraft down to within 14.5km of the lunar surface, over the Sea of Tranquillity, where Apollo 11 was intended to land. The manouevre was completed a second time, with the descent stage jettisoned at the low point of the flight and the ascent stage engine fired in order to climb back up to rendezvous with the Command Module. Although there was a problem with the LM guidance system shortly before the descent stage was jettisoned, which caused the LM to gyrate wildly for about eight seconds, these simulations demonstrated the validity of the lunar rendezvous technique.

After an 8-hour separation, the LM and CM successfully docked, at which point Mission Control displayed a cartoon, specially drawn by Peanuts creator Charles Schultz, showing Snoopy kissing Charlie Brown, with the comment *'Smack. You're right on target Charlie Brown'!* Following the docking, the Lunar Module was cast loose and directed into a solar orbit, while Apollo 10 spent another day in lunar orbit, undertaking photography of the lunar surface and the Apollo 11 landing site in particular.

After eight days the Apollo 10 crew returned to Earth, splashing down in the Pacific on May 27. The mission had been an unqualified success, proving that the entire Apollo system was 'all systems go' and ready for the 'giant step' that Apollo 11 was to represent. On the day the Apollo 10 crew returned to Earth, a large sign appeared in Mission Control at Houston reading '51 days to launch' - the final countdown to the Moon landing had begun! S&S

Kerrie Dougherty is Curator of Space Technology at the Powerhouse Museum in Sydney, and one of Australia's foremost space experts. Make sure you don't miss our next issue, which will be a special Apollo 11 anniversary issue.

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THE SOUTHERN SKIES by Martin George

As the sky darkens in May, we see the Milky Way high in the south, crossing the sky from east to west. The famous Southern Cross is nearly upright, with the Pointers below it and to its left.

To the west, the magnificent constellation Orion is sinking lower each evening. In the east, another prominent constellation is making its evening appearance: the well-known shape of Scorpius, the Scorpion, is seen with his body roughly parallel to the horizon. It is interesting to compare this view of Scorpius with its appearance when it is much higher in the sky; when very low down, it seems to loom larger above the hills and trees. The same effect is seen with the Moon, and is often called the 'Moon illusion'. Other star groups can seem large when near the horizon, but to me, the effect is most noticeable with Scorpius!

Turning to the north, the ancient zodiacal constellation Leo is well placed for observation, and in this issue we shall take a look at a selection of easy objects in Leo for small telescopes - including two or three galaxies!

Regulus (Alpha Leonis) - a blue-white star about 85 light-years from Earth - is the brightest star in Leo. Photo by Steve Quirk.

Easy telescopic sights in Leo

Although Leo appears upside down from our part of the world, it is easy to find. Its brightest star, **Regulus**, is the uppermost star in The Sickle - a distinctive group of stars within the constellation. These stars mark the front leg and head of the lion; his body stretches across to the right, and the star Denebola, the second brightest in the constellation, marks his tail. Leo is one of the few constellations that really does resemble the creature or object after which it was named - but I must admit that the resemblance is much easier to see when it is seen the right way up! Do have a look at it if you ever travel to the northern hemisphere - but for a less expensive view, try to turn your head upside down.

Now for a few objects to see with some simple optical aid. Unfortunately, there is little to see with binoculars in Leo, although the few scattered fifth and sixth magnitude stars near Denebola make me think of a frilly end to the lion's tail! We'll start off by aiming our telescope at Regulus; about three arcminutes away is a 7.7-magnitude companion star that is not difficult to see. Now swing the telescope north and a little east to another of Leo's bright stars, Gamma, also called **Algieba**, which is one of the sky's most celebrated doubles. It was found to be such by Wilhelm Struve in 1831 using what was at the time the world's largest refractor - a 9.6-inch (24.4 cm) instrument in Dorpat, Russia. Then, the two stars - of magnitudes 2.2 and 3.5 - were separated by only 2.5 arcseconds, but now their relative motion has moved them to a more comfortable 4.4 arcseconds apart.

There are several other less bright doubles in Leo, but two of my favourites for the small telescope are **54** and **90 Leonis**. The former consists of 4.5- and 6.3-magnitude stars separated by 6.5 arcseconds, and the latter - found about two-thirds of the way along an imaginary line from Delta to Beta - has stars of magnitudes 6.0 and 7.3, rather closer at 3.3 arcseconds apart.

Leo contains many galaxies, but my favourites are **M65** and **M66**, which are two of the best galaxies in the sky for observation with a small telescope. Readers with reasonably dark skies may like to try spotting them with binoculars; I can just see M66 as a tiny patch of light using my 7x50 pair. The two can be seen in the same telescope field using low magnification, and the larger the instrument, the more obvious their galactic nature becomes, especially in the case of M66.

These two spiral galaxies were discovered not by Charles Messier, as their 'M' designations may suggest, but by the French comet observer Pierre Mechain in 1780. In fact, it is remarkable that Messier was not the first to spot them, as a comet discovered by Messier passed between the two early in November, 1773. A possible reason for the omissions appears in Messier's original catalogue: *'. . . a cause de la*

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Three galaxies (clockwise from top): NGC3628, M65 and M66. Photo by Steve Quirk.

lumiere de la Comete' (because of the light of the comet). See if you can spot the edge-on spiral galaxy **NGC 3628** just to the north. By placing the M65-M66 pair at the southern edge, NGC 3628 can also be included in the field, making a spectacular view.

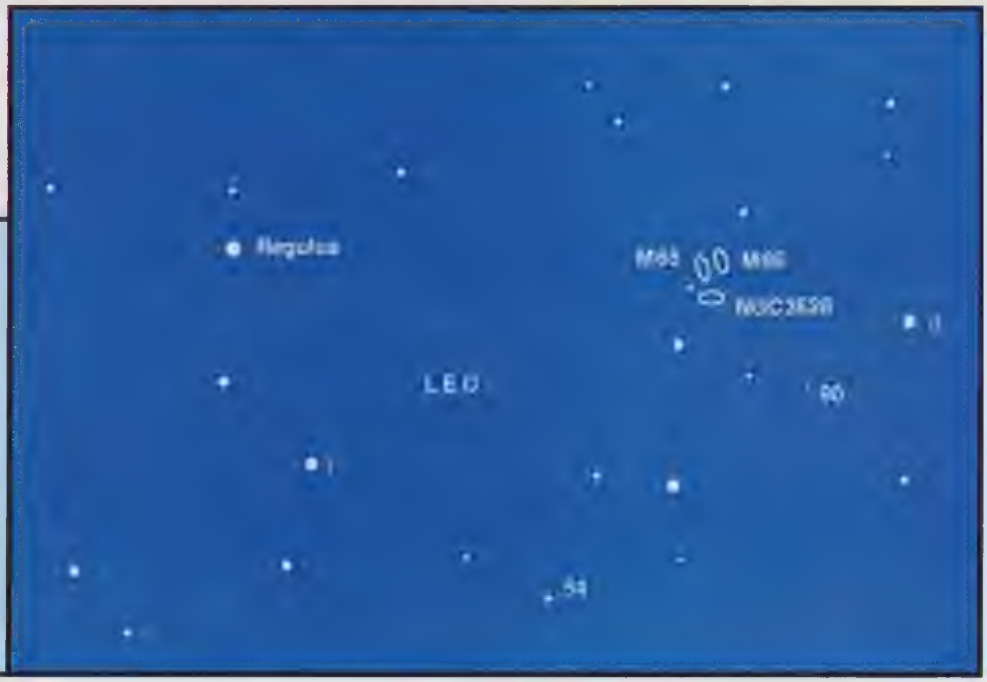
The Planets

The planet to watch at the moment is **Jupiter**, appearing near the border of Libra and Virgo and having reached opposition on April 30. At magnitude -2.5, Jupiter easily outshines the brightest stars. A pair of binoculars will show its four brightest moons, and any small telescope will show some brownish belts on Jupiter's disc. It would be a good idea to familiarise yourself with Jupiter's appearance over the next couple of months, in case any effects of the impact of Comet Shoemaker-Levy 9 in July are visible with your optical instrument (see Planetary Page in this issue. Ed).

Shining brilliantly in the north western evening twilight is **Venus**, now appearing well clear of the Sun. Telescopically, Venus is rather disappointing at the moment, with a disc reaching only 15 arcseconds across by the end of June. Also visible in the evening twilight through the middle of this period is tiny **Mercury**, which reaches a greatest eastern elongation of 23 degrees on May 30, but is poorly placed at a high northerly declination.

In May, **Mars** and **Saturn** are both visible in the morning sky. Red Mars can be seen in the eastern sky before sunrise, moving from Pisces through Aries into Taurus. At the end of June it can be seen a few degrees above and to

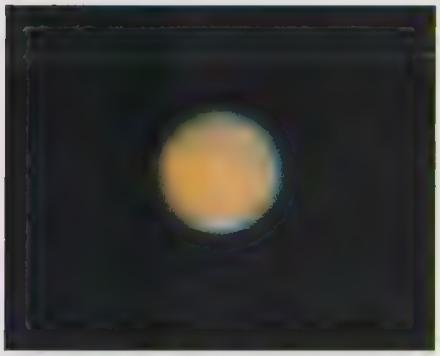
Right: *South is uppermost in this chart, which shows most of the constellation of Leo with stars down to about fifth magnitude. The locations of all of the objects mentioned in the text are shown.*



Coordinates of objects shown on the chart

Object	RA h	RA m	Dec. °	Dec. ′
Regulus	10	08.4	+11	58
Algieba	10	20.0	+19	51
54 Leonis	10	55.6	+24	45
90 Leonis	11	34.7	+16	48
M65	11	18.9	+13	05
M66	11	20.2	+12	59
NGC3628	11	20.3	+13	36

The positions in this table were obtained from *Sky Catalogue 2000.0* (Hirshfeld and Sinnott, ed., Cambridge Uni. Press and Sky Publishing Corp., Cambridge, 1985).



***Left:** Mars is visible in the morning during May and June. Photo by Chii-Sheng Lin - two seconds exposure on Fujichrome 400D.*

the right of the Pleiades cluster, low in the north east. Ringed Saturn is in Aquarius, and by the end of June it is rising in the late evening. The telescope will show that its rings are currently tilted only a few degrees from edge-on: they appear at their 'slimmest' for this year during June.

Finally, a partial eclipse of the Moon occurs on May 25, but it will not be visible from Australasia. The eclipse reaches a maximum at 3h 32m UT, when 24% of the Moon's diameter lies within the Earth's shadow. S&S

Martin George is Director of the Launceston Planetarium and President of the Astronomical Society of Tasmania. He regularly appears on Tasmanian television and radio to cover special astronomical events.

MOON PHASES

Last Quarter
Jun 1, 2.02pm
Jul 1, 5.31am

New Moon
Jun 9, 6.26pm
Jul 9, 7.37am

First Quarter
Jun 17, 5.57am
Jul 16, 11.12am

Full Moon
May 25, 1.39pm
Jun 23, 9.33pm
Jul 23, 6.16am

Times in Australian Eastern Standard Time

Explanation of Terms

This table gives basic data on the position and appearance of the Sun and major planets. The first two columns are self-explanatory. The third and fourth columns, RA and Dec., are the right ascension and declination coordinates for that date - these are much like longitude and latitude on Earth. The fifth column gives the object's angular diameter in minutes (′) and seconds (″) of arc; as a guide, the full Moon is 30 arcminutes across. The sixth column indicates phase, or the degree to which the object shows a 'crescent' - 100% means the planet shows a complete disc; a lesser number indicates the disc does not appear fully illuminated from Earth. The second-last column (Elongation) gives the angular separation (east or west) from the Sun in degrees; the further it is, the better it is for viewing. The final column gives the apparent magnitude or brightness; negative numbers are brighter than positive ones, eg. -1.0 is brighter than +1.0, +1.0 is brighter than +8.0. Around +5.0 is the faintest the unaided eye can see under a dark sky.

Positions of the Sun and major planets for May to July, 1994

See bottom left for explanation of terms.

Object	Date	R.A. h m	Dec. ° ′	Diam. ′ ″	Phase %	Elong. °	Mag.
Sun	May 31	4 30.9	+21 52	31 33.8	-	-	-
	June 15	5 32.8	+23 18	31 30.2	-	-	-
	30	6 35.1	+23 12	31 28.5	-	-	-
	July 1	6 39.3	+23 8	31 28.5	-	-	-
	16	7 40.7	+21 25	31 28.9	-	-	-
Mercury	May 31	6 10.8	+25 9	- 8.3	35	23E	+0.6
	June 15	6 35.7	+21 37	- 11.3	8	15E	+2.8
	30	6 5.1	+18 46	- 11.6	3	8W	+4.1
	July 1	6 3.2	+18 44	- 11.5	4	9W	+3.8
	16	6 13.3	+20 29	- 8.2	33	20W	+0.6
Venus	May 31	6 52.7	+24 41	- 12.6	82	33E	-4.0
	June 15	8 9.3	+22 8	- 13.6	78	36E	-4.0
	30	9 20.9	+17 26	- 14.9	73	39E	-4.0
	July 1	9 25.4	+17 3	- 15.0	72	39E	-4.0
Mars	May 31	2 13.3	+12 36	- 4.4	96	34W	+1.2
	June 15	2 56.6	+16 10	- 4.5	95	37W	+1.2
	30	3 40.4	+19 7	- 4.6	94	41W	+1.2
	July 1	3 43.4	+19 18	- 4.6	94	41W	+1.2
	16	4 27.5	+21 29	- 4.7	93	45W	+1.2
Jupiter	May 31	14 17.9	-12 23	- 43.3	100	147E	-2.4
	June 15	14 13.7	-12 5	- 41.9	100	131E	-2.3
	30	14 11.9	-12 0	- 40.3	99	117E	-2.2
	July 1	14 11.9	-12 1	- 40.2	99	116E	-2.2
	16	14 12.9	-12 10	- 38.5	99	102E	-2.1
Saturn	May 31	22 56.3	-8 36	- 17.0	100	87W	+1.0
	June 15	22 57.9	-8 30	- 17.4	100	101W	+1.0
	30	22 58.0	8 33	- 17.9	100	116W	+0.9
	July 1	22 58.0	-8 34	- 17.9	100	117W	+0.9
	16	22 56.6	-8 46	- 18.3	100	131W	+0.8
Uranus	May 31	19 52.6	-21 27	- 3.8	100	133W	+5.7
	June 15	19 50.9	-21 32	- 3.8	100	148W	+5.6
	30	19 48.6	-21 38	- 3.8	100	163W	+5.6
	July 1	19 48.5	-21 38	- 3.8	100	164W	+5.6
	16	19 46.0	-21 45	- 3.8	100	179W	+5.6
Neptune	May 31	19 39.3	-20 49	- 2.3	100	136W	+7.9
	June 15	19 38.0	-20 54	- 2.3	100	151W	+7.9
	30	19 36.5	-20 58	- 2.3	100	166W	+7.8
	July 1	19 36.3	-20 58	- 2.3	100	167W	+7.8
	16	19 34.6	-21 2	- 2.3	100	179E	+7.8
Pluto	May 31	15 49.7	-5 20	- 0.1	100	161E	+13.7
	June 15	15 48.2	-5 19	- 0.1	100	149E	+13.7
	30	15 46.9	-5 20	- 0.1	100	136E	+13.7
	July 1	15 46.9	-5 20	- 0.1	100	135E	+13.7
	16	15 45.9	-5 23	- 0.1	100	121E	+13.7

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The STELLAR SPHERE

Use this night-sky star map in conjunction with 'The Southern Skies' article on pages 30-32 of this issue.

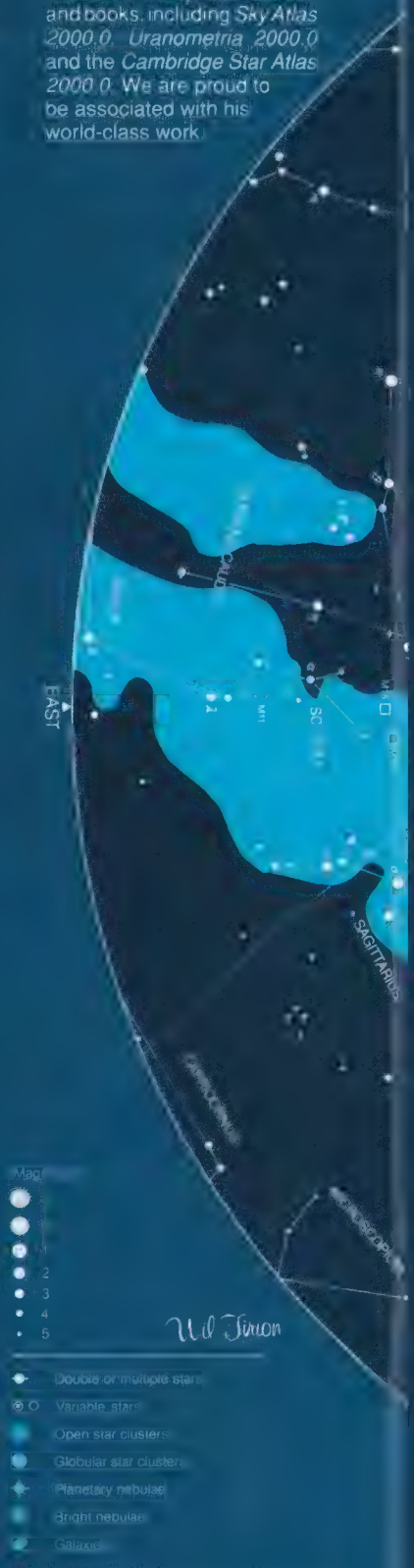
Our main star chart has been prepared specially for SKY & SPACE by world-renowned celestial cartographer, Wil Tirion. Tirion is author and co-author of many star atlases and books, including *Sky Atlas 2000.0*, *Uranometria 2000.0* and the *Cambridge Star Atlas 2000.0*. We are proud to be associated with his world-class work.

June 1, 1994
2.30am

This is a view of the sky looking to the west, early on the morning of June 1. Brilliant Jupiter is easily visible near the border of the constellations Libra and Virgo - it shines brighter than any of the nearby stars. Have a look at the giant planet through a pair of binoculars - you'll see up to four moons strung out on either side of it, whilst any type of telescope will show cloud bands on the planet itself. A lot of astronomers - amateur and professional - will be watching Jupiter carefully during July's comet collision. See pages 30-32 for more details.

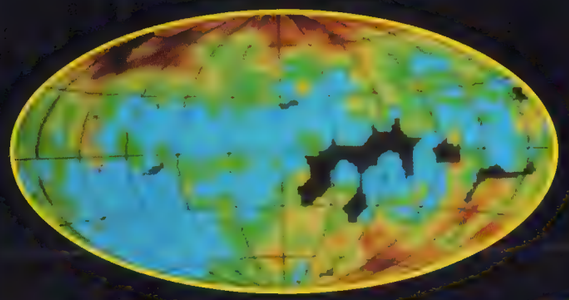
June 27, 1994
6.30pm

The is how the early evening sky looks to the north west in late June. The planet Venus is shining brightly - far brighter than any of the stars, and even brighter than Jupiter. It makes a beautiful sight in the evening twilight, but for observers with a telescope the view is a little bit disappointing - due to its great distance from us, Venus appears very small (120 times smaller than the full Moon). For more details see 'The Southern Skies' on pages 30-32.

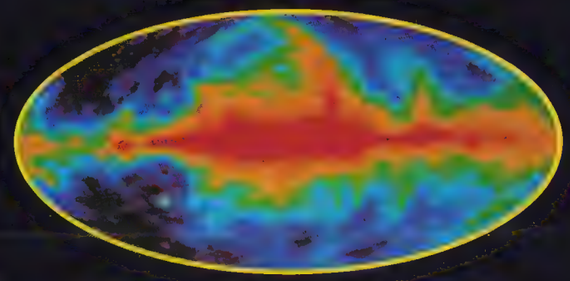


Stellar Sphere appears in every issue of SKY & SPACE Magazine - The Only Astronomy & Space Magazine for Australia and NZ. Published by SKY & SPACE Publishing, 80 Ebley St, Bondi Junction, NSW, 2022. Tel: (02) 369 3344. Fax: (02) 369 3366.

The Milky Way Galaxy



How the Milky Way Galaxy looks at X-ray wavelengths.



How the Milky Way Galaxy looks at radio wavelengths.

This special poster of the Milky Way Galaxy was included free in the June 1994 issue of SKY & SPACE Magazine. For all the latest news in the world of astronomy and space exploration, read SKY & SPACE Magazine - The Only Astronomy & Space Magazine for Australia and New Zealand. Available through newsagencies or by subscription direct from SKY & SPACE Publishing, 80 Ebley Street, Bondi Junction, NSW, 2022. Tel: (02) 369 3344, fascimile (02) 369 3366.

This is a map of our Milky Way Galaxy seen in visible light. It was hand-drawn by Tatjana and Martin Keskula under the guidance of Knut Lundmark of the Lund Observatory, Sweden. The plane of our Galaxy is the bright horizontal band across the width map. The centre of the Galaxy lies in the direction of the centre of the map, but it is not visible due to obscuring dust clouds. Other dust clouds show up as dark splotches throughout the Galaxy. In the lower half of the map are the two Magellanic Cloud galaxies, well known to Southern Hemisphere observers.

THIS CHART IS FOR

11.00pm on June 1
10.00pm on June 15
9.00pm on July 1
8.00pm on July 15

For dates in between, the time can be worked out by simply adding or subtracting four minutes per day. Note that as the night progresses, stars on the western edge of the chart set below the western horizon and others rise above the eastern horizon - this is the effect of the Earth's rotation.

HOW TO USE THE CHART

Hold the chart over your head and align it so that the bottom of the page faces south. What you see on the chart, then, corresponds to the sky for the times listed in the top right-hand corner of this page. The centre of the chart is the point directly overhead, the circumference is the horizon, and the light-blue band is the Milky Way. The chart is based on the latitude of Sydney, but can be used without too much distortion from 20° to 50° south.

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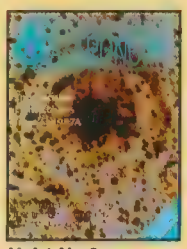

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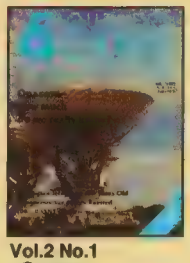

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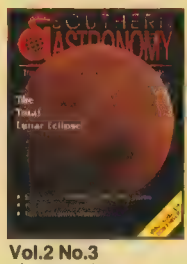

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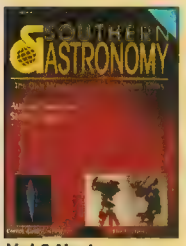

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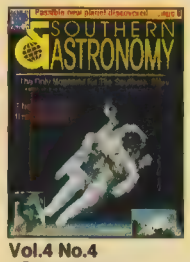

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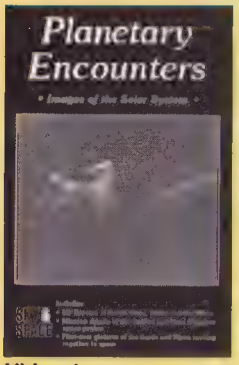

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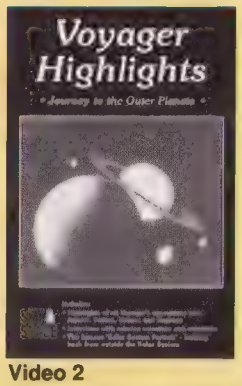

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Join the Sky Patrol!

by Paul Camilleri

With some simple equipment, clear skies, and lots of patience, you too can make discoveries in the night sky. Award-winning sky patroller, Paul Camilleri describes how he finds 'new stars'.

Many amateur astronomers take photographs of the night sky. Some prefer prime focus shots, while others choose to use wide angle lenses. But no matter which method you choose, you can be sure that on each photograph you take, there will be thousands and thousands of stars. And that's not all, for hiding in amongst all those stars might be a new comet or an undiscovered nova, just waiting for you to find it.

For the past several years, I have been taking wide angle photographs of selected regions of our night sky. My aim? To discover new novae. And I'm pleased to say that I've had some measure of success. In this article, I shall outline how you can get started in photographic nova searching and some of the techniques involved.

Why search for novae?

Many stars in the sky (most of them, in fact) belong to binary star systems, where two stars are in orbit around each other. Solitary stars like our sun are the exception rather than the rule. Some of these binary star systems are rather special, comprising a white dwarf star in a very close orbit around a much larger companion star. The white dwarf's gravity draws matter onto its surface from the companion star. When enough of this matter has collected, an enormous thermonuclear explosion takes place all over the surface of the dwarf. In a short space of time, it goes from being a small, dim star to a small, very bright star. After the explosion, it settles down and begins to draw matter from the companion again, and so the cycle repeats. This phenomenon is called a nova, which is Latin for 'new star'.

Professional astronomers are in great need of new novae discoveries in order to test their theories of how these bodies work. But professionals generally are not equipped with the right sort of gear to make nova discoveries, nor are they able to devote large amounts of time to sky patrolling. Thus they rely on amateurs to make many of these discoveries, and to bring them to the attention of the professionals.

So where do most novae occur? Where there is the greatest population of stars - our Milky Way galaxy. If you were to take photographs of the star fields of the Milky Way regularly throughout the year, you would stand a very good chance of picking up several 'new stars'. The ideal search area is as far north and south along the length of the Milky Way that is visible from your location. For someone like myself, in country Victoria, the search area is from southern Cygnus all the way down through Aquila, Sagittarius, Scorpius, Norma, Crux, Carina, Vela and Puppis, and up to Taurus. The most productive section is Aquila to Crux, which covers the galactic centre area, where there are more stars per photograph than in other fields.

Taking sky patrol photos

Once you've decided to search for novae, you must develop some guide-lines on how you will conduct the sky patrol.

The first thing to consider is which camera and lens to use. Any 35mm camera with a 'B' or 'T' setting will do, while the most common lenses used by successful nova patrollers range from 85 to 200mm. The smaller the focal length of the lens, the wider the field. A 35mm wide angle lens will give an image of 25 x 58 degrees on 35mm film; a 50mm lens gives 27 x 41; 85mm gives 16 x 24; 135mm gives 10 x 15; and a 200mm lens will give 7 x 10 degrees.

Something you have to weigh up is image scale to field of view. A 35mm lens will show novae of magnitude 8, while a 50mm lens will reveal novae down to magnitude 9; an 85mm lens gives 10th magnitude, and 135 and 200mm lenses give 12th magnitude.

From my experience, I recommend a minimum of 85mm for the Milky Way. In the past I have used a 135mm lens to discover four novae, but the smaller image scale means that many more exposures are needed to cover the same area of sky. Using exposures of two minutes, an 85mm lens will cover four times the area of a 135mm lens.

Film is another choice you'll have to make. I started off using Kodak's black and white Tri-x, and then moved on to Kodak T-Max which gave a slight improvement in contrast. Hypered 2415 film has finer grain and higher contrast than T-Max, but it is more expensive. T-Max has worked very well for me.

Colour film is not often used by nova searchers, mainly because it decreases your magnitude limit by up to two magnitudes. I recommend you stick to black and white.

The author at work. Using the Stecom method, Paul Camilleri carefully checks negatives of regions of the sky, looking for novae, or 'new stars'.

Now that you've settled on a camera, lens and film combination, the next thing you need to consider is exposure times. If your sky is dark and unaffected by light pollution, an 85mm f/2 lens on 400 ASA black and white film will reach magnitude 12 without sky fogging with just one to two minutes exposure. Exposures over three minutes tend to introduce fogging without any improvement in limiting magnitude.

For the simple purpose of discovering novae, you really don't need to go deeper than magnitude 11; the average brightness of 13 novae discovered by

myself and Bill Liller over the past three years is 8.2.

I won't go into too much detail here about processing, as the method you choose will depend on the film you use and what sort of darkroom set-up you have. I use a simple process: I develop the film in MWP-2 for 10 minutes at 25°C, then bathe the film in a stop bath for 30 seconds, followed by two minutes in Kodak rapid fixer. The film is then washed under running water for 10 minutes and hung to dry.

Searching

To find novae or other new objects, you have to compare two photographs taken some time apart. There are three ways of doing this, but I'll describe here only the one I use. It's the simplest and least expensive.

The system I use is called Stecom (stereo comparator). It's very simple - all you need is a light box (I built a table with a glass top and a fluoro tube behind it), a couple of 8x eye lupes (which are small magnifying lenses), and that's all!

Placing two negatives on the glass top of your light box, position the lupes over the negatives, align them properly and 'stereo fuse' your eyes so that the images coming into each eye are merged into one. Any differences between the two negatives immediately 'jump' out at you! These differences might be dust on the negatives, film flaws, or stars that have changed brightness.

When you find some of these 'new' objects on your negatives, the first thing you must do is check to make sure that they are real. This is done by taking two photographs of the same area each night, separated by a small span of time. This eliminates dust and film flaw problems.

Once you are sure that there is a star that has changed brightness, and is recorded on two negatives at different times on the same night, you'll then need to check atlases and catalogues to see if the object is already known.

Let's look at an example - a long-period Mira-type variable star. Say you examine a negative and find a star that has changed brightness since you last photographed the area - for a Mira variable this would have to be at least a few weeks or months between negatives. On two more recent negatives the star is visible at magnitude 8, but there is no sign of it down to magnitude 10 on a negative taken four months earlier. This looks interesting!

Your next step is to consult a good star atlas, such as *Uranometria 2000* or the *AAVSO Variable Star Atlas*, which plots most variable stars to magnitude 9.5. If you find a variable plotted at the right position, then all you have 'discovered' is a well-known variable star. Time to carry on to the next negative.

But if you can't find a variable star plotted at the right position in the star atlas, you need to delve deeper. You'll need access to a photographic star atlas, the best being *Atlas Stellarum* and *Atlas Fulkaru*, both by Hans Vehrenberg. These atlases are made from photographs with magnitude limits of 14 and 13 respectively, and you can measure positions from them to accuracies of 0.1′ in right ascension and 1′ in declination.

If you find the star on one of these photographic atlases, then it's only a matter of measuring its position and consulting a variable star catalogue to see if it is already known. If there is no image of the star, it could still be a variable that was fainter than the limit of the atlas when the photographic plates were taken.

Now that you have a fairly accurate position, you need to consult the catalogues. The main catalogue for variable stars is the *General Catalogue of Variable Stars*, 4th edition, 1982 (GCVS). If you can't find it there, you'll have to consult the *New Suspect Variable Catalogue* (NSV). In this catalogue are listed suspected variables not included in the GCVS. If you have no luck here, the next step is the 'name lists' to the GCVS. These are issued every two or three years and list new variables that have been named and will be included in the next edition of the GCVS. If you still cannot find your star listed, try the symbiotic and red star catalogues, which lists stars that may be variable. (I would heartily recommend that all observers get hold of a copy of Liller's excellent *The Cambridge Guide to Astronomical Discovery*. It's a good read, and deals with all aspects of discovering novae, comets and asteroids.)

If all these measures fail to identify

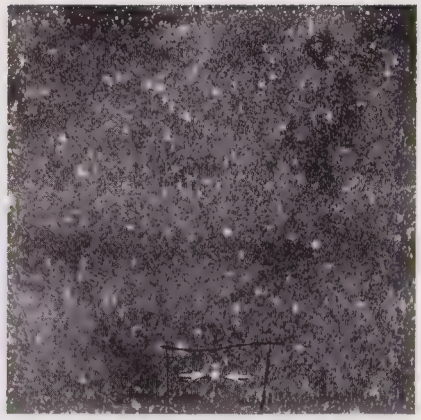
Would you have picked the nova in these photographs? ***Left:*** *The 'before' photo of the constellation Ophiuchus.* ***Right:*** *The 'after' photograph reveals a newcomer - Nova Ophiuchi 1991 (arrowed).*

Paul Camilleri - 1994 Berenice Page Medal winner

Paul Camilleri is the recipient of this year's Berenice Page Medal. The Medal is awarded by the Astronomical Society of Australia every two years to an amateur astronomer who has contributed outstanding work to the science of astronomy. The Council of the Astronomical Society of Australia had this to say about Paul:

'Paul Camilleri's work is outstanding. He has discovered 9 novae and 7 Mira variables in only three years of observing using simple techniques. His work is of the highest technical standard and his enthusiasm and motivation are clearly apparent. He has become, over a short time, a regular contributor to the International Astronomical Union Circulars and is already one of the top few nova discoverers of all time. He has developed his techniques to an extent that they could be employed by many other amateurs without difficulty.'

We're sure all readers will join with us to congratulate Paul, and wish him continued success in his sky patrolling.



The crowded star fields of Sagittarius make for painstaking patrol work, but the density of stars increases the chance of finding a nova.
Left: *The 'before' field of star clouds in Sagittarius - photo taken on uly 15, 1991.* ***Above:*** *Camilleri's Nova Sagittarii 1991 made its appearance just two weeks later, as shown in this enlargement from the discovery photograph.*

Useful information

You should be able to purchase atlases and catalogues through the two main variable star observing organisations:

Variable Star Section
Royal Astron. Soc. of NZ
Dr F.M. Bateson
PO Box 3093
Greerton
Tauranga
NEW ZEALAND

AAVSO
25 Birch St
Cambridge
Massachusetts 02138-1205
USA

Atlas Stellarum can be obtained direct from the author in Germany:
Dr H. Vehrenberg
Postfach 140365
4000 Dusseldorf 1
Germany

A detailed listing of catalogues and atlases can be found in Bill Liller's book, *The Cambridge Guide to Astronomical Discovery*, Appendix H, pages 237-244 (Cambridge University Press, 1992). Readers who want more information can contact me at RMB 2013, Cottons Rd, Cobram, Vic., 3644. **Paul Camilleri.**

the star, you can be sure you have found a new variable star. The final step to make sure that it is real, is to actually go out and visually confirm it. You can then report it to the variable star section of your nearest astronomical society or the Variable Star Section, Royal Astronomical Society of NZ, who will have their regular observers monitor the star. Once its type and period of variability are known, it will be given a name and added to the variable star lists.

But could it be a nova?

Now let's look at the example of a suspected nova. Say you find a new 8th magnitude object on one of your negatives that was not present on films taken only two or three weeks ago - it could well be a nova.

Carry out all the same checks described above to eliminate it as a variable star, then confirm it visually and have someone else confirm it visually. If it passes all these tests, the last thing to do is to check whether it is an asteroid. The Minor Planet Ephemerides (EMP) lists positions for many asteroids, but only for an 80-day arc around the times of their oppositions. You might have spotted an asteroid well away from opposition, but still bright enough to be mistaken for a nova. An Englishman, Nick James, has written a very good computer programme which will compare the position of your suspected nova against more than 5,000 asteroids.

If after all these checks you still are unable to identify the star, you may report it to the Central Bureau for Astronomical Telegrams in the USA, or to a nearby professional observatory and ask them to report it for you. If the observation has been confirmed, an electronic bulletin will be sent to observatories all around the world to alert them to the discovery.

Once the discovery notice has been issued, someone at a professional observatory does a follow up observation in order to obtain a very accurate position measurement. For my discoveries this is usually done by Rob McNaught at Siding Spring (NSW) or Alan Gilmore at Mount John University Observatory (NZ). And whenever possible, other professional astronomers in Australia or South America make follow-up spectrum observations in order to learn about the nova's chemical and physical characteristics.

All the measurements and observations are reported on alert circulars sent around the world. The discovery of a nova is an exciting occasion, and the circulars can make very interesting reading. But there's no time to stop and gloat - you must get straight back into your patrol if you want to discover yet another one. And sooner or later, you will. S&S

Paul Camilleri is the winner of the 1994 Berenice Page Medal for contribution by an amateur to the science of astronomy. He has discovered nine novae, and 7 new variable stars. The story of Paul's first nova, Nova Ophiuchi 1991, can be read in our Astro Tales section, November 1990, page 54.

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TEST REPORT:

Celestron C5+

Review by Peter Ward

The Celestron C5+ has been hailed as a versatile, 'go anywhere' telescope. Peter Ward put one through its paces and found that it does live up to its reputation . . .

The C5+ optics and drive come packed in a double-walled, foam-lined cardboard container. The equatorial wedge and table mount are packed separately in a styrofoam lined box. Whilst the packaging is adequate, an optional foam-lined container is available, which in the long-run would be well worth the additional expense.

The telescope comes with a 66-page manual and an accessory guide. The manual takes you through set-up and operation, and includes clear instructions on how to align on the celestial pole, how to care for and collimate the optics plus some additional observing material. Celestron have continued their high standard of documentation.

The optical tube is fitted with a dual-purpose doveplate/photo-tripod bracket. The doveplate allows the tube to quickly and easily slide onto the fork arm; the tripod bracket enables the 'scope to be mounted to any photographic tripod, and with an appropriate adapter can be used as an f/10 1,250mm telephoto lens. Two plastic-capped screws are fitted to the doveplate after attaching the telescope to the fork arm to stop the telescope from sliding off the mount should you accidentally release the locking clamp. They work too! (No prizes for guessing how I know this to be true).

The 5x24 finderscope has a high-quality objective lens with no field stops, making it a good, functional accessory. Standard equipment also includes a Kellner 25mm eyepiece, coated right-angle prism and lens caps for all optical components.

The telescope is attached to the equatorial wedge with three bolts into the drive base. Though Celestron probably had a commendable 'no tool' set-up in mind, I found my fingers slipped on the bolts' plastic caps. I would have preferred to use an Allen key, or at least a different style of moulding which would allow a better grip.

Celestron's C5+ with drive base, equatorial wedge and table-top mount.

The C5+ with drive, weighs a modest 7.5 kilograms, making it a very manageable package. It can be easily picked up and carried with one hand - in fact, the fork arm has a built-in handle for just that purpose. The equatorial wedge has an easy-to-read latitude scale, plus a broad base with bubble level and an adjustable foot on one side.

Taking advantage of the telescope's 'table top' design, I placed it on a solid Jarrah outdoor table. It didn't take me long to realize this was not a good idea. With the telescope near the northern edge of the table, aligning on the south celestial pole was easy. However, as soon as I swung the telescope around to examine some northern sights I ran into a problem: I had to either stand up and crank my head around to an uncomfortable angle to reach the eyepiece; move the telescope to the southern side of the table (and ruin my polar alignment); or drape myself over the table from the southern end. I also discovered that my 'solid' Jarrah table was the optical mounting equivalent to a bowl of jelly, quivering at the slightest touch. No doubt a concrete pier would work extremely well, but practically speaking, a tripod is by far the most effective way to use C5+ in the field.

On a tripod the C5+ is a delight to use. The declination slow motion control is remarkably smooth. Whilst the RA control is coarse in comparison, it too allows the 'scope to be easily adjusted. Locking clamps are within easy reach, firm and positive to use. The focuser is smooth and precise, and there was no play in any of the test unit's bearings.

Gazing through the telescope, I first checked for image shift while focusing. At first I couldn't see any; it wasn't until I used an illuminated reticle that a shift of seven arcseconds was noted. With a focal length of just over one metre this is barely noticeable - an excellent figure.

The drive motor uses a spur gear, which initially seemed to me to be a retrograde step (I must admit to some scepticism prior to using the 'scope). I am now converted, as the drive proved to be remarkably smooth with only small gear meshing errors. At most, the drive drifted some 30 arcseconds from its optimal position, which was easily corrected by a quick stab on the keypad of the drive corrector hand paddle.

The drive runs on a standard 9-volt alkaline cell, which according to Celestron will last for 50 hours before it needs replacing. I don't doubt this at all, as the battery I was using continued happily driving the telescope even after several evenings of heavy use.

The C5+ easily lends itself to any number of photographic accessories. With an optional declination motor, off-axis guider, prime focus adapter or piggy-back bracket, the C5+ can be readily transformed into a 'go anywhere' astrophotographic instrument.

Prior to performing my usual '850 gram test', I had reservations about the overall rigidity of the C5+ mount. Early versions of the C5 had two fork arms, and while I am not a fan of fork mounts, two seemed like a better idea than the one provided on the current model. I suspended an 850-gram weight from the focuser then released it, noting the initial flexure and vibration dampening time. While all vibrations decayed in just over 3.5 seconds (an acceptable result) the flexure

Focus testing the C5+. The lower two images show the Airy disc on either side of focus; well-defined rings denote a smooth figure to the telescope's mirror. The two upper images (at half-scale) indicate a slight astigmatism, plus a small spherical error evident in the difference of the symmetry of the images on either side of focus.

of 650 arcseconds had me checking to see whether I had secured all of the mounting bolts. This much flexure is equivalent to a star centred in the field of a 12.5mm eyepiece, totally leaving the field when given this modest load. To confirm the tripod was not at fault, I placed the telescope on a solid concrete ledge and repeated the test: the result was the same, though the dampening time reduced to 2.8 seconds. If there is an Achilles heel to the C5+, this is it, which is a pity as it is singularly at odds with the fine engineering evident elsewhere on the 'scope.

As a last comment on the rigidity of the C5+ mount, while photographically testing the drive (which confirmed the good result I had seen at the eyepiece), I noticed a slight kink in the star trail at the start of the exposure. This was not the drive, but a vibration from the camera's mirror retracting. This could easily ruin an otherwise perfectly guided photograph, so astrophotographers are advised to use a piece of dark card as an interim shutter or lock the camera mirror up, prior to taking an exposure.

The C5+'s tracking performance is good. The blip at the beginning of star trail was caused by the camera's mirror retracting.

Star testing the optics, the intra- and extra-focal images showed smooth, evenly spaced diffraction rings with a slightly brighter outer border on the intra-focal image. In short, the optics were smooth with a good figure. Moving closer toward focus, the image became slightly elongated. I made a record of the star test using a CCD camera (see photograph at the top of the page).

Unfortunately, the CCD camera could not record in detail the in-focus stellar image, which had a well defined Airy disk with an only slightly brighter-than-normal first diffraction ring. In summary, the optics had a slight astigmatism, with a very small spherical error. For most, the less than perfect performance would go totally undetected. I subsequently examined two other C5's and found their level of optical correction to be simply excellent.

In practical terms the C5+ easily resolved several double stars, though the brighter-than-normal first diffraction ring made the task a little harder than usual. At low powers the Moon was crisp and very bright. At higher powers some images lost some 'snap' but were still fine. I was pleasantly surprised to find that many Messier and other deep sky objects were bright and easy to see. In a side-by-side test, objects barely hinted at through my own (rather old) 10cm SCT were clearly seen through the C5+; the difference was surprising, despite the C5+'s expected advantage of an extra 2.5cm of aperture. The C5+ also had the better contrast, demonstrating that Celestron's coating technology has improved markedly over the years.

In re-releasing the C5+, Celestron has produced a telescope that has many very fine qualities. A readily transportable, yet powerful package, that can be easily adapted to astrophotography. As a powerful introductory telescope, the C5+ is an excellent choice. As a 'go anywhere' photo/visual telescope, it is alone in the marketplace - it is ideal for eclipse chasers due to the almost perfect image scale of the sun and moon on 35mm film at prime focus. My thanks to Astro Optical Supplies in Sydney for supplying the test unit and for their excellent back-up service whenever I had a query or problem. S&S

Peter Ward is our regular equipment reviewer.

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TEST REPORT:

Meopta Proximus 100

Review by Geoff McNamara

If you're looking for an inexpensive, easy-to-use beginner's telescope, the Meopta Proximus 100 may be the one you're looking for. We recently tested one, as Geoff McNamara explains . . .

The Meopta Proximus 100 is a 100mm Newtonian reflecting telescope on an alt-azimuth mount. It comes with two eyepieces and instruction manual.

The telescope is supported by a sturdy tripod that extends to about 1,300mm, allowing the eyepiece to be placed at a convenient height for children or adults. The timber is strong and attractively finished. The tripod legs are stabilised by metal straps, on which sits a metal accessory tray.

The alt-azimuth head is well made and easy to use. It locks easily and firmly, and has slow motion controls on both axes that are smooth and well within reach when the observer is at the eyepiece. The nature of alt-azimuth mounts means that unless they are of the fork design, a counterweight is needed to stop the telescope falling back as soon as it points anywhere other than the horizon. Meopta are well aware of this, and the Proximus 100 comes equipped with a counterweight.

The telescope tube is attached to the mount with two adjustable straps, allowing easy rotation of the tube. This is an important consideration when using a Newtonian on an equatorial mount, but doesn't really make any difference on an alt-azimuth mount.

Now to the optics - 100mm f/10 mirror, nice bright coating, small secondary. By the time the telescope was taken out and set up, the optics were slightly out of alignment. This is common with all Newtonians, so naturally I looked for the collimation screws . . . but couldn't find them! Then I noticed a thin metal plate at the rear of the 'scope, held in place by three screws. Sure enough, the collimation screws were behind this panel. The factory has secured them with 'lock-tight' compound to stop them moving during transit. A quick turn with a screwdriver broke the lock-tight and allowed me to adjust the collimation.

Meopta's Proximus 100 is an inexpensive 100mm Newtonian reflector, suitable for beginners.

The helical focuser is its best feature - the motion is smooth and easy.

Again, a quick inspection did not reveal the location of the secondary mirror adjustment screws, however Meopta assure me they are there under another cover - this telescope is obviously designed to be tamper-proof.

Okay, so how does the telescope perform? The first time I used it was in projection mode to observe last November's transit of Mercury across the face of the sun. The Proximus 100 performed well, and gave a nice, clear image. The performance of the telescope at night is about what you'd expect from a 100mm reflector - nothing special, but good for a small 'scope.

The telescope uses a helical focuser, and this is its best feature. The focusing motion is smooth and easy - light enough for fine focusing, but not so free that the focus changes when you bump it. The fit of the eyepieces was a bit tight. The eyepieces are held in the drawtube by friction; slits in the drawtube allow you to change the tightness to suit yourself.

The Proximus 100 is equipped with a 5x30mm right-angle finderscope. This is a beaut little finder, and has its own helical focuser. It has a clear, wide field of view.

The telescope is fairly easy and quick to set up, and is easy to use. This is a beginner's telescope, and would provide satisfaction for most newcomers - before aperture fever starts to bite. I've used 100mm reflectors in the past and found that I soon wanted to move to something larger. But if you're a beginner, the Proximus 100 will get you started. Our thanks to Meopta for supplying the unit used in this review. S&S

Geoff McNamara is an optics expert who teaches at Sydney Technical College. Geoff hosts our regular Planetary Page column for planetary observing enthusiasts. He also is heavily committed to public education of astronomy; he has a regular astronomy programme on radio station 2SER in Sydney.

The Meopta Proximus 100 sells for $795 and is available from:
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This year's SKY & SPACE ASTROFEST - October 6 to 9, inclusive - promises to be even better than last year's, with an extension from three days to four, more involvement from professional astronomers, and more time for socialising and swapping ideas with other participants.

The SKY & SPACE ASTROFEST is intended for amateur astronomers of all levels of experience, not just for the advanced. In fact, we particularly want to encourage beginners to come along, and so we were very pleased to welcome a large number of novices to last year's event. It's a great opportunity for beginners to meet with more experienced amateurs and to pick up lots of tips from them.

We've lined up a great programme of professional guest speakers for the 1994 SKY & SPACE ASTROFEST, including Dr John Whiteoak (Deputy Director of the Australia Telescope National Facility) who will bring participants up-to-date with the fascinating world of radio astronomy; Professor Jeremy Mould (Director of Mount Stromlo and Siding Spring Observatories) who is the leader of one of the four main Hubble Space Telescope observing programmes; Dr Keith Taylor (Anglo-Australian Observatory) who will describe the enormous new optical system being installed on the Anglo-Australian Telescope (which we will all get a chance to see during the guided tour); and David Malin, Australia's world-famous astrophotographer, who will lead a discussion on astrophotographic techniques - no self-respecting amateur astronomer should miss this session!

A special highlight will be our participation in a special 'History of Siding Spring Observatory' seminar, at which most of Australia's professional astronomers will be gathered. Plus there will be the guided tours through the optical and radio observatories, bush-walking, and lots of observing! Numbers are limited, so send for your information kit today - see page 30 for details.

Sydney society donates books

The British Astronomical Society (NSW Branch) and the Donovan Astronomical Trust have joined forces to provide the NSW State Library with a selection of top quality specialist astronomy books. The Library will be able to make use of the books through its normal borrowing systems, enabling borrowers to obtain astronomical information to which they would not normally have access.

BAA president, Mike Chapman, handed over the first batch of books to librarian, Margie Brown, at a ceremony at the Library earlier this year. Titles include Astronomy of the Southern Sky, Astronomy for Every Kid, How to Make a Telescope, Exploring the Night Sky with Binoculars, Handbook for Visual Meteor Observations, and several more. Total value of all the books is $319.

Mike Chapman of the BAA presents a selection of books to Margie Brown at the NSW State Library.

Queensland astro societies gather

The first Queensland Astrofest was held August 11-15, 1993 at the Duckadang Lions Camp. Attended by about 70 people (including spouses and children) from seven astronomical societies. The camp is about two hours drive north-west of Brisbane.

The Queensland Astrofest began on Wednesday, and by Friday nearly all participants had arrived. Events included a swap and sell on Saturday morning, held under the barbecue rotunda followed by short reports from amateurs about observations, photography and instruments. In the afternoon, Jeff Ryder, Curator of the Sir Thomas Brisbane Planetarium, delivered a particularly fascinating talk about obscure amateur astronomers who later became professionals. Afterwards we watched a video of Patrick Moore, in which he reminded amateurs of their ability to make observations not usually possible by professionals.

Saturday evening was the time for presentation of awards. The award for the most innovative use of materials went to Alasdair Murray for his Dobsonian telescope. Steve Mencinsky took the award for the most unusual telescope for his 45-cm dobsonian (probably the most deserving prize!). The best Dobsonian award went to Peter Marples for his 41-cm f/4.5, while Gary Erwin won the award for the best equatorially mounted 'scope for his 20-cm reflector.

Participants of the 1993 Queensland Astrofest.

Despite four clear nights, the seeing was sometimes poor. The air was affected by smoke from burnoffs near the campsite, but nevertheless, a great time was had by all. It gave members from most Queensland astronomical societies the chance to hang out and to do observing with other astronomers. The 1994 Queensland Astrofest will be on in August. Like 1993, the 1994 Queensland Astrofest will be mainly a Queensland event, but we hope that interstate amateurs interested in attending can make the trek to Queensland. For more details, write to Michael Horn, 7/108 Oxlade Drive, Newfarm, Queensland, 4005.

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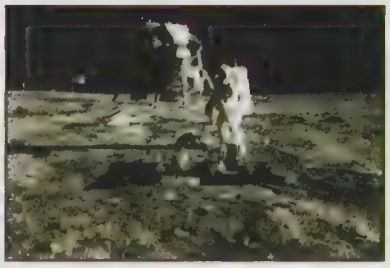

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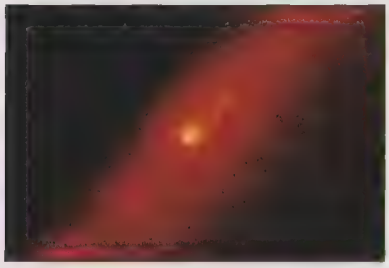

Look out Jupiter!
Astronomers around the world are preparing themselves for the observing opportunity of a lifetime - July's collision between a comet and the giant planet Jupiter. We provide a complete rundown of what's expected to happen.

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In Part 2 of 'Build a better Newtonian telescope', Steve Lee discusses choosing the right secondary mirror for your telescope, and finds that size really is important . . .

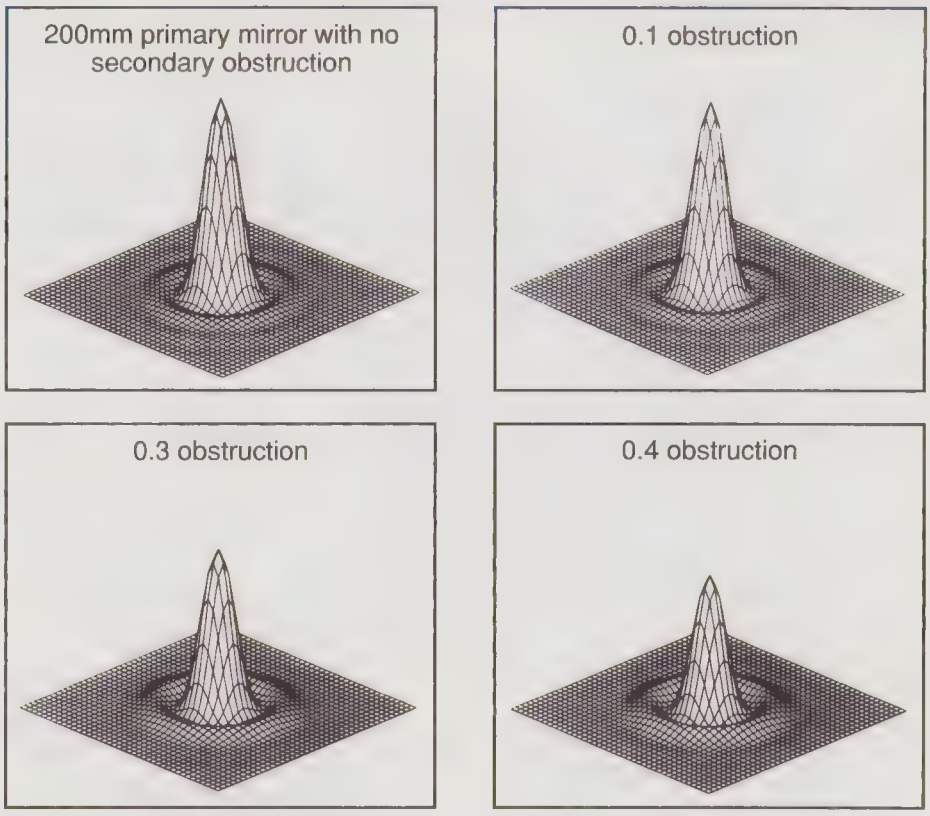
In my last article I discussed how the focal ratio of the primary mirror of a Newtonian telescope affected its performance. This article deals with the choice of the secondary mirror, and also touches on a number of other important points.

A Newtonian secondary mirror is an optical flat, placed in the centre of the tube at 45° to the optical axis to divert the light to a convenient location for viewing. So that it causes the minimum obstruction to the incoming light, the secondary is usually elliptical in shape; the ellipse is chosen to look like a circle at the 45° angle. Again, a very simple arrangement; what can go wrong here?

The problems are two-fold. The secondary must be large enough to not waste any light directed towards it but not too large to cause excessive obstruction. Let's examine the second point first: how big can the secondary mirror be in relation to the primary before its size starts to degrade the image?

As I've mentioned in this column several times, a point image like a star does not form a point in the focal plane of a telescope. Instead, diffraction spreads it out to a disc (the Airy disc, named after George Airy, the first Astronomer Royal of England who performed the mathematical analysis which showed that a point source seen through a telescope would form a disc and a series of ever-fainter rings). The angular diameter of this disc is proportional to the wavelength of the light and the aperture of the telescope (or its linear diameter to the focal ratio of the telescope).

This defines the angular resolution of any telescope. A larger diameter telescope can see finer detail than a small one because its Airy disc is smaller. A related point is when you consider that extended sources (like the Moon and planets) effectively are made up of lots of point images - each point will be imaged by the telescope into an Airy disc and surrounding rings. The extraneous light that neighbouring rings flood on top of the discs affects the contrast of the image. If there is more light in the rings than there should be, then planetary views will be less well-defined because the image will have a lower contrast.



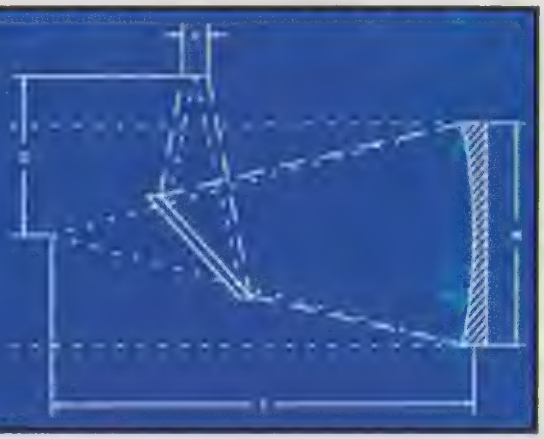
Examine the diagrams above; they show a pseudo-3D idealised view of a star at the focal plane of a telescope. For a 200mm telescope, the area shown is two arcseconds across. (The images scale linearly; 1 arcsecond across for a 400mm aperture, 4 arcseconds for one of 100mm.) The six plots show how the star's energy is progressively redistributed from the central disc to the outer rings as the size of a central obstruction increases. The first plot shows the ideal case of no central obstruction; the first ring is barely noticeable. There's not much change with an obstruction of 0.1 of the diameter, but by the time the obstruction is only 0.2 the first ring is quite apparent. Once the obstruction reaches 0.3 the degradation of the image is quite serious. The final plots at 0.4 and 0.5 obstructions are, without question, appalling. The table on the next page puts some numbers to these plots.

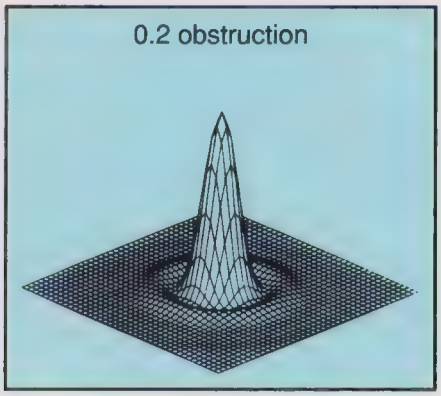
What can we deduce from this? That we had better keep the size of the secondary mirror below 20% of the

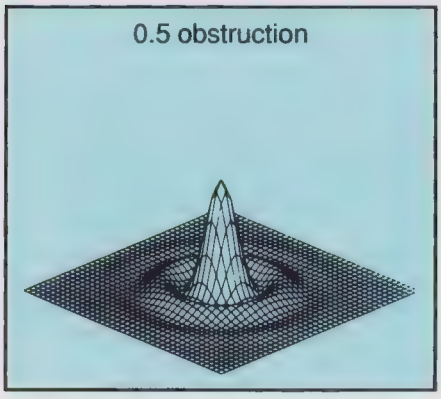
To calculate the size of a Newtonian secondary mirror, d, use:

$$d = C\frac{M + v}{f} + v$$

where C is the distance it is inside the focus of the primary, whose diameter is M and whose focal length is f. Finally, v is the linear size of the field of illumination as shown below. (This formula isn't perfect, but it is as good as necessary for all practical purposes.)







primary's if we want to obtain high contrast images from our telescope. And yet I see many telescopes made today with excessively large secondary mirrors. While this may be necessary for photography, there is no excuse for it in a visual telescope.

So what influences the size of the secondary mirror? A formula for computing this size is given in the box at lower left. Given that the diameter of the primary mirror (M) is fixed, as will be the intended width of the fully illuminated field of view (v), what can we do to keep the diagonal as small as possible? We can modify the two remaining parameters to our advantage; either make f larger, or keep C as small as possible.

The first option agrees with the conclusion of the last issue - maximise the focal ratio. Let's look at a few numbers - we'll compare a 15cm f/10 with an f/4. We'll keep the linear field fixed at 10mm, and the distance inside focus as 200mm. Feeding these numbers into the above formula yields a diagonal size of 28.7mm for the f/10, but 56.7 for the f/4. That's an acceptable 19% obstruction for the f/10, but a whopping 38% for the f/4! It's no wonder that short focal ratio instruments give poor planetary images.

The effect of a secondary mirror on the image of a star

Obstruction* diameter	% of light in disc	% light in first ring	% light in all rings
0	84	7	16
0.1	82	9	18
0.2	76	14	24
0.3	68	22	32
0.4	58	28	42
0.5	48	35	52

* As a fraction of the primary mirror diameter.

(Lest I be abused for being biased, a comparison against a fixed angular field rather than a linear one only slightly changes the answer for the f/4 instrument to 52.7mm, or 35%.)

The second option is most useful when designing a photographic instrument where we desire to keep the focal ratio small. Again we'll look at some real numbers. The value for C of 200mm in the above calculation is made up from the radius of the telescope tube plus an allowance for the focuser. The tube must be a little larger than the mirror, say 190mm diameter (95mm radius). This gives us 105mm for the focuser; large but not excessively so when compared to some I've seen. But we can do better than that. You can buy short-style focusers for just this purpose. For visual use, we should be able to get the distance down to around 30mm. What does this do to the size of the diagonal? Our f/10 comes down to 21.7mm or 15%, and more significantly our f/4 improves to 39.2mm or a much more acceptable 26%.

It actually becomes easier to achieve a small value for C with larger mirrors. The allowance for the focuser remains constant and only the tube radius increases. Try these calculations for a 30 or 40cm mirror.

Unfortunately, for a photographic Newtonian we can't easily achieve such a short spacing, but it is clear from the above examples that it is the focuser we must concentrate on improving to allow us to minimise the secondary size. We'll look at mechanical aspects in our next issue. S&S

Steve Lee is a telescope operator and computer programmer at the 3.9-metre Anglo-Australian Telescope at Siding Spring Mountain. He's also an accomplished amateur astronomer and telescope maker from way back.

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MY OBSERVATORY

During the early months of 1993, the science department staff at Grace Lutheran College (Redcliffe, Qld) faced a pleasant dilemma: in which of two observatories should the College's principal telescope be housed - our campus observatory, or our dark sky site?

In 1989, the College established its first observatory at its outdoor education site in the Blackbutt Range 150 kilometres north-west of Brisbane. Taking its name from the adjacent state forest, the Googa Outdoor Education Centre was a near-perfect location for an observatory, at an elevation of 520 metres and well away from light polluted city skies. (Grace Lutheran College is a co-educational college located in the suburb of Rothwell on the Redcliffe Peninsula some 40 kilometres north of Brisbane.)

It had formerly been a Forestry Department camp, and a building suitable for an observatory already existed in the form of the 'hazardous chemical store'. A substantial steel-framed, three-metre-square building, it was located (for obvious reasons) in a large cleared area well away from all other buildings. After 'decontaminating' the structure, power was connected, the interior insulated and lined, furniture built and a roll-off roof and permanent pier were installed to accept a Celestron 8.

Aperture fever

After some two and a half years of operation, 'aperture fever' struck and the C-8 was replaced with a Celestron C-14 fitted with Advanced Astro Master digital setting circles and database. The Astro Master has greatly reduced the time required to locate objects invisible to the naked eye. With thirty or so eager students waiting their turn at the eyepiece, the esoteric pleasure of slowly finding celestial wonders is a luxury that few college astronomers can afford!

The modern observatory at Grace Lutheran College, Redcliffe, Brisbane.

Despite being a very large telescope, the C-14 was chosen as the most suitable telescope for its intended role because the eyepiece is located at normal standing height for a student. The thought of routinely sending thirty teenagers up a step ladder in the dark with a wonderfully inviting open telescope tube so close to the eyepiece, as might be the case with a Newtonian, would cause severe anxiety in most astronomers. The fully sealed optical tube of the C-14 was another plus factor, as the Blackbutt site can at times be somewhat dusty. Additionally, the telescope's solid construction together with the unobtrusive fork mount has proven to be a boon in our sometimes congested observatory at Googa. These factors, together with the overall ease of operation and its ability to perform as a 'jack of all trades', has made the C-14 easy to live with in an educational environment.

A pleasant dilemma

In 1992 a decision was taken to extend our administration and science buildings, with the new wing of the science department being a second floor extension. A suggestion that perhaps the second story could go a little higher and encompass an observatory was placed before the college council and unanimously accepted.

Therefore, by early 1993 we faced a dilemma: which telescope should be installed in the observatory on campus - the C-8 or the C-14? A decision had to be made soon, as construction had almost reached the stage where the pier had to be installed and the remainder of the observatory built around it.

The Googa Observatory, 150km north-west of Brisbane. This shed was formerly a hazardous chemical storage facility!

Without question the more favourable dark sky site was Googa. But with a two-hour drive each way, getting a class of students to Googa and returning them home that same evening certainly did not encourage frequent or spontaneous use of the observatory. On the other hand our almost eight hundred students, their parents and our local community, all of whom we had planned to give access to our observatory, lived nearby the College.

So the decision was taken to return the C-8 to Googa and make use of the extra light-gathering power of the C-14 on campus. At Redcliffe we have Moreton Bay to the east, Deception Bay to the north, and only moderate development to the west - with the C-14 we have found that even when facing directly toward the sky glow of Brisbane, we can still discern faint deep sky objects such as galaxy NGC 5128.

The campus observatory comprises a 4.5-metre colourbond steel dome which rotates on 12 rollers. Both the dome rotation and the main slot opening are power driven by single-phase motors with reduction drive gearboxes. A manually-operated lower flap completes the dome assembly which, together with the ring beam, was manufactured and installed by Actualdome Observatories in Brisbane. Dome rotation is controlled by push buttons located next to the pier; all rollers and operating mechanisms are fully enclosed for safety. To say that we are pleased with the quality of manufacture and operation of the dome is an understatement.

Putting it to good use

The observatory has three levels. From the physics laboratory below, students ascend a flight of stairs to a workbench area at a mezzanine floor level. Here,

they can dark adapt while awaiting entry to the observatory, and returning students can write up their observations under dim light before descending to the physics laboratory. From the mezzanine, a short flight of stairs takes you up to a landing and storage area overlooking the physics lab, and from here a third flight of stairs brings you onto the observation deck itself.

The pier for the C-14 is 3.4-metres in height and passes, without touching, through the timber observatory floor to be dyna-bolted to the concrete mezzanine floor below. A slotted base-ring allows for minute polar alignment adjustments of the tapered and gusseted cylindrical steel pier which was manufactured for the College by a local blacksmith. This is the third pier that we have obtained from this craftsman and all have proven to be rock steady!

The observatory is equipped with a chart table, eyepiece and accessory storage drawers, lap-top computer, solar filter, camera equipment and timepieces for local, universal and sidereal time. A portable equatorially-mounted 11cm Newtonian reflector is available for students to learn telescope familiarisation and field work. Our student computer network and the observatory complement one another by virtue of the fact that we can run the TS-24 telescope simulator program in the computer laboratory and then follow up with a practical session in the observatory.

'First light' for the observatory, if not for the telescope, was celebrated in July last year by the College's participation in the Association of Independent Schools Queensland annual 'Days of Excellence' scheme. Our Day of Excellence in Astronomy was attended by students representing five different high schools. The day involved 'hands-on' exercises aimed at enabling the students, many of whom had no previous experience in astronomy, to develop the skills to predict which celestial objects would be in range of the telescope on any particular evening, and then using star charts, computer software and reference books, identify and locate a randomly chosen object.

Inside the dome: pictured are the author plus his son and daughter, standing next to the C-14.

The observatory on campus is a wonderful asset for the students and staff, and one which we hope to share with parents and the wider community. Yet we have not forgotten our 'hazardous chemical store' at Blackbutt - it continues to operate, and for all the convenience that a dome offers, I must admit that it is hard to match the breathtaking experience when the entire roof is rolled back at crystal clear, dark sky site. On such occasions I cannot help but affirm our observatory's motto, taken from Psalm 19: 'The heavens declare the glory of God. The skies proclaim the work of His hands . . .' S&S

John Shobbrook is director of the Grace College and Googa Observatories, and computer network manager at Grace Lutheran College. He has been a devoted amateur astronomer for 15 years, and has taught primary and secondary students for 10 years.

Joining hands across the heavens

On March 10, 1994, and again on March 17, Grace Lutheran College became the first educational institution in the Southern Hemisphere to take full control of a telescope at a major observatory in the Northern Hemisphere. At around 2.00pm our time (8.00pm Californian time) on those dates, using a computer on campus we took control of one of Mount Wilson's telescopes, slewed it to objects of our choice and then using a CCD attached to the telescope captured, and then downloaded a number of images via modem from California to Brisbane. We attempted a third connection on March 24, but we were defeated by overcast skies above Mount Wilson.

We used *The Sky Astronomy Software* (to drive the Mount Wilson 60cm telescope) and *SkyPro CCD Astronomy Software* (to capture and download the images). The telescope was equipped with an ST-6 CCD camera, and at our end we used a 486DX-50 colour lap-top computer with Local Serial Port Controller software via an internal modem.

Year 8 students Vanessa Shobbrook and Trent Simpson with Rick Yessayian at Grace College. On the screen is the CCD image of the Crab Nebula which they took by remotely controlling a telescope in the USA. (Courtesy of Brisbane Courier Mail.)

The opportunity to undertake this experiment was due to the combined efforts of (at Mount Wilson) Mr Gilbert Clark, the Director of the 'Telescopes in Education' project at the Mount Wilson Institute, and (at Grace College) Mr Robert Flegg and the staff of the science department, and Mr Richard Yessayian, a American astronomer and science teacher who travelled to Australia to supervise the technical aspects of the operation. His travel was kindly funded by the Australian-American Educational Foundation in Canberra. **John Shobbrook.**

IN ORBIT by Kerrie Dougherty

Following the successful flight of the first Russian cosmonaut on board the Space Shuttle during the STS-60 mission in February, NASA announced the selection of the two astronauts who are now training in Russia for the reciprocal mission to the Mir space station, in 1995.

Veteran Shuttle astronauts Norman Thagard and Bonnie Dunbar were selected as the prime and back-up crew members for the three-month space station mission next year. Thagard, with both medical and engineering degrees, has served as Mission Specialist on four Shuttle flights. Dunbar, who has a PhD in biomedical engineering, has made four Shuttle flights and has recently served as Deputy Associate Administrator for Microgravity Research at NASA Headquarters.

The selection of the two astronauts is part of NASA's expanding co-operation with Russia in the development of the new international space station, which will replace the now-defunct Space Station Freedom programme. Between 1995 and 1997 there will be up to 10 Shuttle flights to Mir, which will include rendezvous, docking, re-supply and crew transfer missions. At least four US astronaut stays on Mir are planned, to eventually total more than two years of on orbit time. In addition, a second Russian cosmonaut, Vladimir Titov, will fly on the STS-63 Shuttle mission in January 1995, while two cosmonauts will join the STS-71 crew in June 1995 for transfer to Mir.

As prime candidate, Thagard will be launched on board the Soyuz TM-18 mission to Mir in March next year. He will join two other cosmonauts to spend approximately 90 days on the space station, carrying out medical and scientific experiments. In June 1995 the Shuttle Atlantis will dock with Mir as part of the STS-71 mission. Thagard and his cosmonaut companions will then return to Earth on the Atlantis, being replaced on Mir by the 'Soyuz TM-19' crew, who are to be ferried up on board the Shuttle.

Because Russian mission planning and training requires a back-up crew member, Dunbar will be undergoing training with Thagard, although she has no definite flight assignment in the ongoing programme of joint space missions. However, her training will qualify her to take up a flight assignment either on a later flight to Mir, or on one of the future Mir-rendezvous Shuttle flights. Because of the lack of a definite flight assignment, it is believed that NASA actually found it difficult to find an astronaut willing to serve as back-up in Russia. Many astronauts actually viewed the Russian assignment as a 'hardship post' because of the economic turmoil and relative lack of amenities in the former Soviet union.

In addition to the two astronauts in training, another astronaut, Kenneth Cameron, has been selected to manage NASA activities at the 'Star City' cosmonaut training complex and the Russian mission control centre at Kaliningrad.

Cameron, who has flown as pilot and commander on two Shuttle missions, has been assigned as Director of Operations-Russia. His responsibilities will cover all aspects of NASA relations with the Russian Space Agency for joint space projects. It is expected that he will also command one of the early Shuttle docking missions to Mir.

Space probe update

Although originally scheduled to be turned off in April, the Magellan Venus probe has been given a reprieve, in order to allow it to complete the gravity mapping of Venus.

NASA is providing an additional US$1.7 million, which will enable scientists to operate the spacecraft until

The Magellan spacecraft at Venus.

September or October, enough time to map up to 97 per cent of the venusian gravity field.

Launched in 1989, Magellan has exceeded its original mission goal of creating a radar map of Venus. Last year, an aerobraking manoeuvre (where the spacecraft 'dipped' several times into the upper atmosphere to slow it down) was used to change the spacecraft's orbit from a highly elliptical one to a low, circular orbit. This enabled it to commence the gravity mapping mission.

The latest NASA budget proposal includes funding requests for four new Mars missions between 1996 and 1998. Modest by the standards of the lost Mars Observer, which they would largely replace, these four small spacecraft will be developed quickly and have some duplication of instrumentation. This would avoid the complete loss of mission that occurred with Mars Observer, should any one of the spacecraft fail to reach Mars.

NASA is examining the possibility of launching the Cassini probe to Saturn from the Space Shuttle, as a result of concerns over the reliability of the Titan 4 launch vehicle currently proposed.

Although NASA had decided to remove space probe launches from the Shuttle manifest, due in part to the unreliability of the Shuttle's launch schedule, concerns over Titan 4 rocket failures have prompted NASA to reconsider a Shuttle launch for the US$1.4 billion mission. Too heavy to be launched on any other US rocket, a Cassini launch via the Shuttle would require two flights: one to carry the probe to Earth orbit and another to ferry up a custom-built three-stage solid fuel booster that would propel the probe to Saturn. A spacewalk would be required for the final assembly in orbit.

NASA is currently considering the cost-effectiveness of this proposal against the cost and risks of a Titan 4 launch.

Darling Clementine

The US Ballistic Missile Defence Organisation (BMDO)'s Clementine space probe has been orbiting the Moon, generating a multi-wavelength map of the entire lunar surface, which scientists will use to identify geological structures and rock types on its surface.

Built by the US Naval Research Laboratory, Clementine was originally conceived as a test programme under the Space Defence Initiative (SDI or Star Wars), to test a range of sensors being developed for the Brilliant Eyes missile surveillance system that was to form a key part of SDI. Although the SDI Organisation has now become BMDO and the Star Wars missile defence concept is dead, the need for lightweight missile defence sensors remains and Clementine has lived on as a space-qualifying mission to ensure that the delicate detector hardware can survive the rigours of the space environment.

With a total cost of around $75 million (including launch), Clementine was built

Artist's impression of the Clementine probe.

in less than two years and has been widely hailed as an example of how NASA should implement Administrator Goldin's push for 'better, faster, cheaper' deep space missions. NASA did not participate in the development of the project, although the Deep Space Network, including Australia's Tidbinbilla, is now providing tracking support for the spacecraft and NASA scientists are analysing the imagery.

Launched on January 25, Clementine has six sensors, the largest weighing only 1.9 kilograms. The probe began sending back images from the Moon in late February. Among its many early images was a view of the Apollo 16 landing site. However, no remnants of that landing, or of the other Apollo missions, had been seen in the images received up to early March.

After completing its Moon mapping mission, Clementine is scheduled to rendezvous with the near-Earth asteroid Geographos, the first time that a spacecraft will investigate one of these close cosmic neighbours. If the spacecraft retains sufficient velocity after this encounter, it will be re-targetted to rendezvous with another asteroid, 1983RD, in October next year.

The Clementine programme is currently being transferred from the control of the BMDO to the US Navy. Plans to build a second Clementine, in which NASA had intended to participate, have been shelved in order to divert the funds to other sensor technology research. S&S

Kerrie Dougherty is Curator of Space Technology at Sydney's Powerhouse Museum, Australia's first permanent space exhibition.

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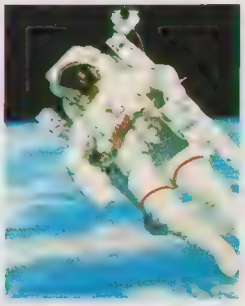

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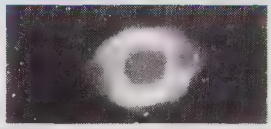

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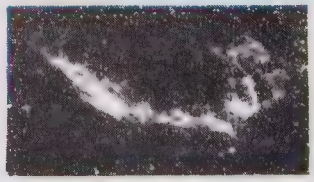

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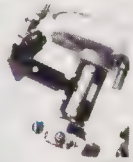

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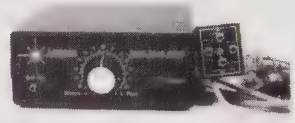

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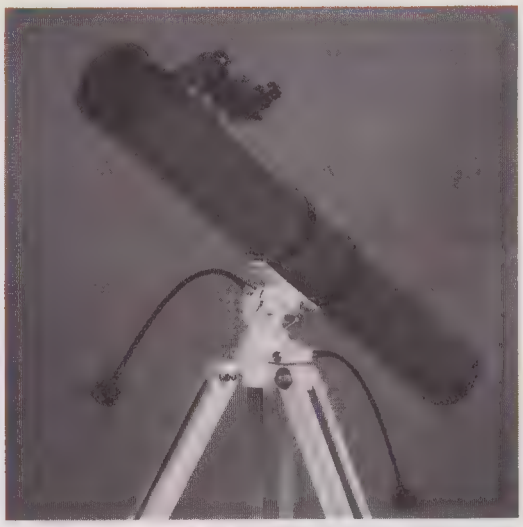

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VARIABLE VIEWS by Peter Williams

Binoculars are one of the amateur astronomers' most neglected optical instruments. Peter Williams gives us some hints for their use, and picks two easy stars for binocular observers to try . . .

All too often do I hear people lamenting about not possessing a large telescope, or having no telescope at all. This is a surprisingly common feeling amongst many amateurs, both newcomers and old hands alike.

When asked if they own a pair of binoculars, 'yes' is the common reply, but most often I am given the impression that they feel binoculars are of little or no value for astronomical observing. This, of course, is a grossly inaccurate misconception as binoculars are a very much underrated astronomical instrument. Many experienced observers will testify that they typically 5° to 7° field of view provided by binoculars make them ideal for the study of our Milky Way's large-scale structures and that they will reveal a surprisingly large number of deep sky objects, including many within the Magellanic Clouds. Binoculars are also an invaluable tool of many comet observers and those who monitor the changing light of the brighter variable stars or conduct a visual nova search.

Are binoculars best?

I do not intend to discuss the pros and cons of the different binoculars available, as there is no shortage of 'experts' just waiting for you to ask such questions. However, in my experience it is appropriate to suggest a pair of 10x50mm binoculars, because of their higher magnification, will provide a slightly darker field and give improved contrast to show fainter stars more clearly when compared to the classic 7x50mm 'night binoculars'.

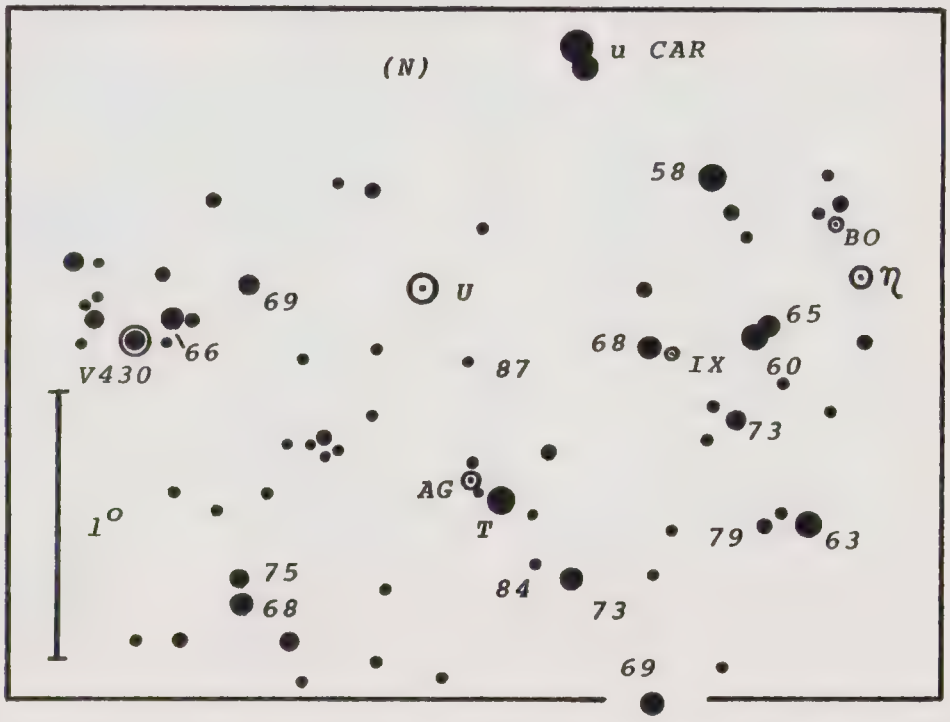
This phenomenon can be expressed by a simple mathematical formula which first came to my attention in David Seargent's 1982 book, *Comets - Vagabonds of Space:*

$$x = (A/M)^2$$

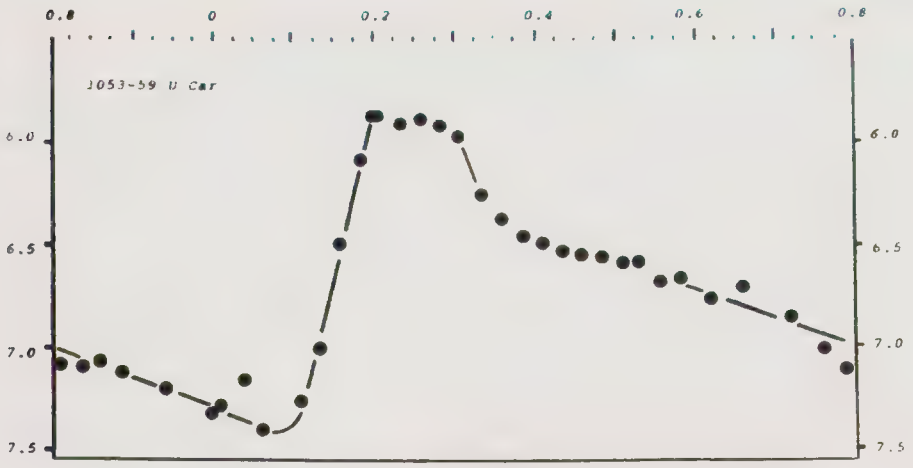
where A is aperture in mm and M is magnification. By this rule, a value close to or higher than 50 will suggest good night binoculars with a bright field, whereas a lower value will indicate a darker field of view. Comparative values for common binoculars are: 7x50mm = 51, 10x50mm = 25, 11x80mm = 53, and 20x80mm = 16. I have not seen reference to a lowest acceptable value for astronomical observing, but my 20x800mm binoculars are still very impressive. As with all things, however, the choice is up to the individual.

Another great advantage of binoculars when compared to a large telescope is the ease with which they can be transported and readied for an observing session, so much so that observations can even be made through broken cloud should a bright and transient sight be present. This also makes them ideal to take away on holidays when the telescope must be left at home to make room for other important things (such as the family).

Within the light grasp of binoculars are literally dozens of variable stars which can be followed through all or part of their light cycle. Stars chosen for binocular observation will depend upon the limiting magnitude (ie. faintest magnitude) attainable from any particular location, and will be subject to changing local conditions and observer experience. As a guide, 10x50mm binoculars will regularly show stars to better than 9th magnitude from my suburban backyard where the naked-eye limiting magnitude is a little fainter than 5.0. However, the normal 'operating range' is usually between magnitudes 4 and 8, while stars brighter or fainter than this are observed with the naked eye or telescope. Often there is an overlap between the various instruments and as



Identification chart for U Carinae based on Chart 452 of Series II Charts for Southern Variables, courtesy of VSS, RASNZ. It shows stars to a little fainter than 8th magnitude and can be used to identify and estimate the brightness of U Car, AG Car and Eta Carinae.



Light curve of the variable star U Carinae. Note how the maximum brightness occurred later than predicted by catalogue data (indicated by the zero mark on the top scale).

there are few strict rules when observing it is often best to do what feels right on the night.

The 10x50mm are always hand-held, as I have found this more convenient than tripod mounting when working quickly between star fields - with a little practice, much of the shake associated with deep sky observing can be overcome. Unlike deep sky work, the variable star observer is not concentrating on a single object for any length of time. When working on the fainter stars or those fields which are high overhead, I often use a folding chair, almost lying in it with my elbows supported on the arm rests as I hold the binoculars.

Binoculars are ideal on holidays when the telescope must be left at home to make way for other important things (such as the family!).

In contrast, the 20x80mm binoculars are almost always tripod mounted, because of their weight and magnification. These are well-suited to stars between magnitudes 8 and 11 and have proven ideal for following variables which, for some reason, are inaccessible with the telescope. Examples which spring to mind here include supernova 1987A when it was skirting the southern horizon, and more recently fades of the RCB stars R CRB and V 854 Cen when close to conjunction with the sun. With all aspects of observing, comfort and ease of operation are of the utmost importance.

Two easy stars for binocular observers

One of the many binocular variables favourably placed this time of year is the cepheid U Carinae, whose brightness is well suited to binoculars. Situated in a field to delight most deep sky observers, U Car lies between the Eta Carinae Nebula (NGC 3372) and the brilliant open cluster NGC 3532. It's catalogued data suggests a magnitude range of 5.7 to 7.1 with a period close to 38.8 days. Long-period cepheids such as U Car require an observation every several days to ensure adequate coverage of their light cycle, even during periods of bright moon, provided care is taken when making the observation and only quick glances are used.

U Car is one of the few long-period cepheids readily accessible through binoculars and we in the Southern Hemisphere are truly fortunate in having this and the nearby l Carinae at our fingertips. Current theories of stellar evolution suggest the long-period cepheids are very luminous stars and therefore evolving rapidly (by astronomical standards). Small changes in chemical abundances at the star's core are thought to result in relatively large changes to the observed period and shape of the light curve. The amateur, armed with nothing more than a pair of binoculars, is therefore well-placed to acquire the observations over many decades which may reveal any such changes. Indeed, the observed period of U Car has been shown to change slightly over time.

The accompanying light curve is a based on 99 visual estimates I made during the 1993 observing season. It clearly shows the rapid rise to maximum typical of these stars, wherein U Car brightens by 1.6 magnitudes in just six days. This is distinctly quicker than indicated in the General Catalogue of Variable Stars, but in good agreement with preliminary results from a study of this star by Newcastle-based amateur, Mati Morel. The subsequent decline is more gradual. An interesting feature is the slowed rate of fading some seven days after maximum: U Car remains close to magnitude 6.5 for about one week. Also clearly evident is the discrepancy of almost eight days between the time of predicted maximum (indicted by the zero on the top scale) and that shown by the observations. A similar but smaller discrepancy was also noted by Morel, suggesting that the Catalogue may be slightly in error. Further investigation of U Car is currently underway by the Variable Star Section of the Royal Astronomical Society of New Zealand.

Within the same binocular field of view is the SD-type variable, AG Carinae, a star which has been unusually active of late. Another star well suited to binocular observation, AG Car recently rose to its brightest since 1981, attaining magnitude 6.1 in November, 1993, and remaining at that brightness through to at least early February.

The SD variable stars are believed to be very massive and highly luminous stars which are also somewhat unstable, and are among the prime candidates for supernova explosions. Indeed, evidence of AG Car's unstable past is the faint whispy planetary-like nebula PK289-0.1 which was probably expelled during an outburst 1,000 or so years ago. This nebula is an interesting challenge for deep sky observers with large Dobsonians or to astrophotographers and CCD imagers. S&S

Peter Williams is a leading authority on variable stars and observing techniques. He is an important contributor to many international observing programmes.

PLANETARY PAGE by Geoff McNamara

With Comet Shoemaker-Levy about to crash into Jupiter this winter, now is the time to prepare by honing your planetary observing skills.

The biggest observing event of 1994 has to be the coming collision of comet Shoemaker-Levy 9 with Jupiter in July. The exact consequences of this impact are unknown, and this adds to the excitement. There may be large-scale changes in Jupiter's appearance, or there may be no change at all. We just don't know. But whether you want to contribute to the observational record of this once-in-a-lifetime event, or just see the results of the impact for yourself, now is the time to get to know Jupiter.

Even if some sort of change does occur, even to the experienced observer Jupiter may not look any different after the impact! Jupiter's cloud tops are, to say the least, turbulent. Unless you're familiar with the planet's 'normal' state, you may not notice anything unusual after Shoemaker-Levy has completed its fiery plunge. So over the next couple of months, take some time to get to know Jupiter's pre-impact appearance, and practice recording what you see.

Jupiter' belts and zones

To see details in Jupiter's clouds requires a telescope of at least a 15cm aperture (reflector) or 8cm (refractor). As always, the telescope should be clean, well-adjusted, and rock steady. The magnification you use depends on how good your telescope is and the 'seeing' or steadiness of the atmosphere at the time. Too much magnification and you'll get a large but blurry image; too little and the image will be too small to see any detail. My approach is to use the highest magnification that still allows a clear image.

When you look at Jupiter through a telescope the most obvious features are the dark brown belts and cream-coloured zones that run parallel to its equator. The diagram above shows the 'official' nomenclature of Jupiter's belts and zones. Unfortunately, Jupiter never looks quite as simple as this when seen through the eyepiece. The planet's appearance is constantly changing: single belts can appear double; double belts can have one component missing; large sections of double belts can be invisible. So the diagram represents a sort of 'average appearance', even if the planet never actually achieves this average!

When recording your observations you should abbreviate each belt or zone's name. The system is fairly obvious, if long-winded. To identify a belt or zone simply use the first letter of each name: the North Equatorial Belt is written as 'NEB'; the South Temperate Zone becomes 'STZ', and so on.

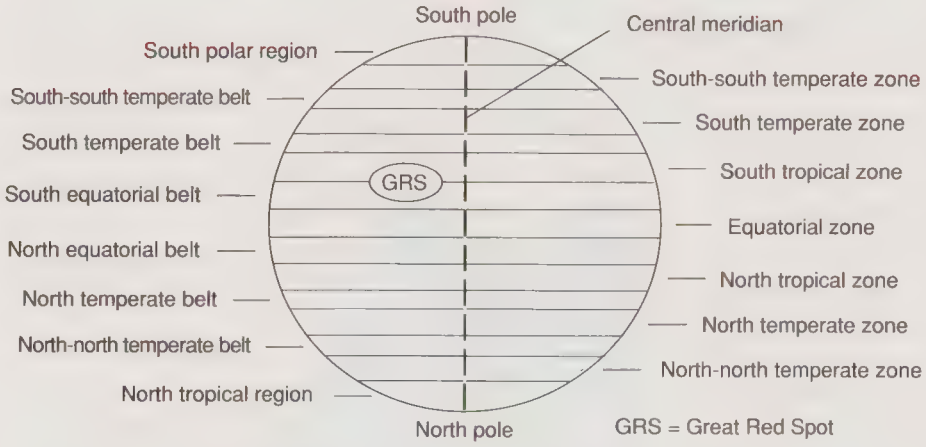
The equatorial belts are divided into north and south components. To identify the component, simply place a small 'n' or 's' after the main abbreviation. So for example, the North Equatorial Belt's south component would be written as 'NEBs'.

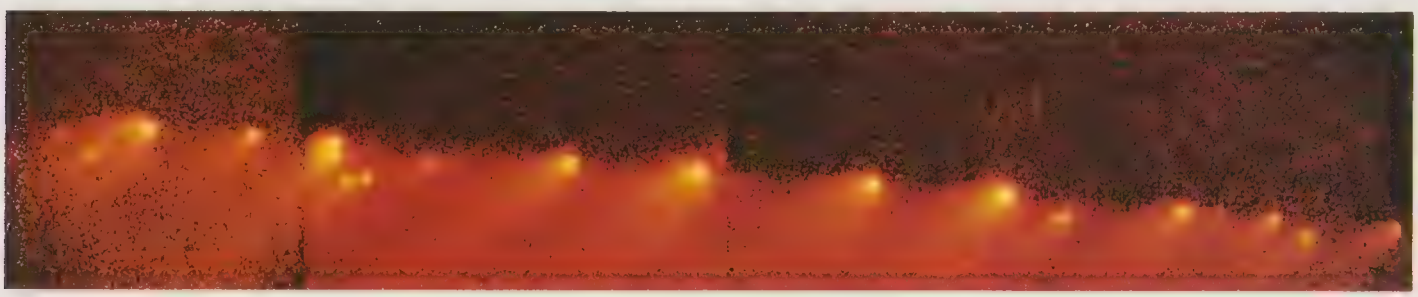
Finally, each belt and component has a north and south edge. So if you saw something on the south edge of the North Equatorial Belt's south component, you'd describe its latitude as 's-NEBs'. That's all there is to describing latitude on Jupiter. What a relief!

Looking for cloud features

So let's have a look at the general appearance of Jupiter. Remember that the planet's appearance is continually changing, so anything I write here is subject to your confirmation! The equatorial belts will be easiest to see and can be picked out with even a 60mm refractor. Between the equatorial belts is the Equatorial Zone. Under good seeing conditions you can sometimes see a thin, faint Equatorial Belt in the middle of this zone. Projections from the North Equatorial Belt (NEB) often can be seen arching into the Equatorial Zone. At the very least, the southern edge of the North Equatorial Belt appears irregular.

Jupiter's cloud belts and zones





***Below:** A Hubble Space Telescope mosaic image of twenty-one pieces of Comet Shoemaker-Levy 9 on their way to fiery destruction in Jupiter's cloud tops.*

To the north and south of the equatorial belts are the temperate belts. Earlier this year I found the north temperate belt (NTB) to be quite thin and distinct, certainly the darkest of all the belts. The south temperate belt (STB) - where the white ovals discussed in last issue's Planetary Page are to be found - can be as dark as its northern counterpart, or so faint as to be almost invisible. A fascinating area to watch is the South Tropical Zone and the adjacent SEB and STB. This is a very turbulent area, especially around the Great Red Spot. Try sketching the patterns and comparing them a week or two later to see if any changes have occurred.

Features become more difficult to see the closer you look to Jupiter's poles. The South-South Temperate Belt (SSTB) can become confused with the South Temperate Belt, while the North-North Temperate Belt (NNTB) is usually rather faint. Finally, the North and South Polar Regions are almost always bland and featureless, the south polar region being fainter.

The types of individual features you can see are described using a standard system of names and abbreviations. As you know from looking up into Earth's sky, clouds have an infinite range of shapes and sizes, and are temporary features. Jupiter is one big collection of clouds, and even the Great Red Spot and the White Ovals are not considered permanent. If you have trouble deciding what to call a feature, remember that good communication sometimes needs more words, not less. So a description of a 'cross between a festoon and a projection' is okay. Making a rough sketch often is the best way of all.

Transits and timings

So far we've described the latitudes and types of features. But what about longitude? The idea of a fixed longitude system on Jupiter makes about as much sense as a map of a cloud in the Autumn sky. Even the Great Red Spot and the White Ovals drift around the planet with respect to each other. Jupiter's cloud features drift because the planet spins fastest at the equator, and slowest towards the poles. So what can you do?

There's only one way out of this mess: take an average! Because the rotation varies from one latitude to the next, the rotation rates at different latitudes have been grouped into 'Systems'. There are four rotation systems associated with Jupiter, but for our purposes we only need two - System I and System II.

System I refers to latitudes within the equatorial belts, and has a rotation period of 9h 50m 30s. Anything outside these belts, that is to the north and south of the NEB and SEB respectively, is described using System II - rotation period 9h 55m 41s. The five minute difference may not seem like much, but it is cumulative. So after about 119 Jovian days the equatorial regions will have gained one extra rotation on the rest of the planet. (Incidentally, if I ever see a feature near the division between the two systems, I generally record its longitude according to both systems.)

The results may be spectacular. We just don't know what will happen, and that's all the more reason to look!

Let's say we saw a projection from the south edge of the North Equatorial Belt's south component. Or in the words of a seasoned Jupiter observer 'proj, s-NEBs'. Because it's inside the equatorial region, we'll use rotation System I.

The only meridian we can see with any certainty on Jupiter is the 'central meridian', an imaginary line that bisects the planet from pole to pole. By using the rotation rates mentioned earlier, the longitude of the central meridian can be defined for any time of day. As the planet rotates, the longitude of the central meridian will increase. The longitude of the central meridian for any given day and time can be determined using tables found in most astronomical yearbooks plus a bit of arithmetic. While not a true longitude such as can be defined on Earth, the longitude of Jupiter's central meridian does allow us to determine the longitude of any other feature.

Now, because Jupiter rotates so quickly, features move across the planet in a matter of minutes. To determine the longitude of a feature, record the time at which it crosses the central meridian - this is called a 'transit'. Work out what the longitude of the central meridian is at the time of the transit and you'll also know the longitude of the feature.

If it is large enough, make transit timings of the preceding edge, centre and following edge of the feature. Taking an average of the three longitudes will give you a more accurate reading. Further, the difference between the longitude of the preceding and following edges gives you a measurement of the feature's size.

But what will be seen?

This completes a permanent record of the feature's position in both longitude and latitude. The only things to be added to the observation is a record of the magnification used, the seeing conditions at the time (0 = hopeless to 10 = perfectly still) and transparency of the sky (1 = completely opaque to 5 = perfectly clear).

By comparing observations from a large number of observers, errors can be either averaged out or removed altogether. Observations like these have been carried out by amateur astronomers for many years, and now constitute a near-continuous record of the atmospheric behaviour of Jupiter for the last several decades.

But the behaviour of Jupiter's atmosphere may change with the impact of comet Shoemaker-Levy 9. Just what will happen when twenty-odd large chunks of ice plunge into Jupiter's cloud-tops is unknown. At the time of the impact Jupiter will be well placed for Australian observers - a good 60 degrees above the horizon at sunset, just right for a few hours comfortable observing.

The latest predictions suggest that the comet will impact in Jupiter's southern hemisphere, which means it's even more important to get to know the general appearance of the planet before the event. That Jupiter's southern half is typically turbulent means that any effects the comet may produce could be disguised quite well. In other words, even experienced observers may not see anything that can be immediately pinned down to the cometary impact.

On the other hand, the results may be spectacular. We just don't know what will happen, and that's all the more reason to look! So take advantage of the still winter evenings and get to know Jupiter. S&S

Geoff McNamara is our regular planetary writer and one of Australia's foremost planet observers - he hosts his own astronomy programme on radio 2SER in Sydney.

Reviews

Atlas of Neptune
by Gary E. Hunt and Patrick Moore
Cambridge University Press
128 pages, hardback, $45.00
ISBN 0 521 37478 2

Atlas of Neptune is a sister work to Hunt and Moore's earlier *Atlas of Uranus*. Continuing with that theme, the authors have produced a beautiful book covering everything you could ever think to ask about the planet Neptune.

Atlas of Neptune begins with 'Neptune in the Solar System', a chapter which describes the scale of the Solar System, the orbits of the planets, and the differences and similarities of each of them. The authors use the journey of Voyagers 1 and 2 to visit the four gas giants (Jupiter, Saturn, Uranus and Neptune) in turn, describing their atmospheres, satellites and rings.

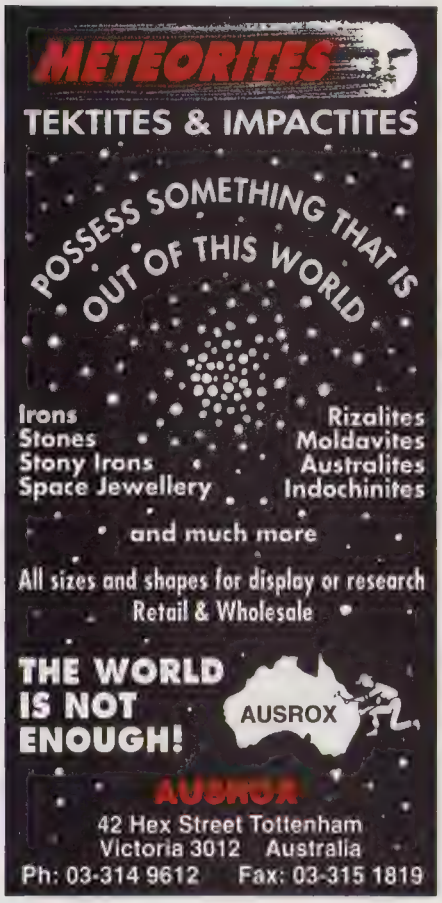
Following that is a chapter on the discovery of Neptune, which is a fascinating tale in itself, full of politics and personalities. It includes a great collection of historical plates of the people who played important roles in the discovery and understanding of giant blue planet - W. Herschel, G.B. Airy, J.C. Adams, U.J.J. Le Verrier and others.

The next few chapters illustrate the difficult task scientists faced in their attempt to understand and describe the enigmatic orb. From Earth, even through the largest of telescopes Neptune is only a small, furry disc. Some observations hinted that the planet might have incomplete rings, but the results were very ambiguous.

That situation did not change significantly until Voyager 2 came along. Hunt and Moore describe the elaborate systems onboard the Voyager spacecraft, and the network of ground stations involved in tracking it, including Australia's Parkes Radio Telescope and the NASA dish at Tidbinbilla near Canberra.

Hunt and Moore then take you step by step through each of Neptune's major features and properties. First comes the atmosphere, the only part of Neptune we can actually see directly. It comprises 85 per cent hydrogen, 13 per cent helium and 1-2 per cent methane - it is the latter which gives Neptune it's blue colour. Cloud bands, hazes and the Great Dark Spot - an anti-cyclonic storm system the size of the Earth - are explained.

Then follows chapters on the strangely tilted magnetic field (which surprised everyone when it was discovered by Voyager), the rings - which share many of the properties of other ring systems, but which nevertheless have some unique features - and the many moons. Before the Voyager encounter, Neptune was known to have only two moons - Triton and Nereid. Voyager added another six, including one, Proteus, which is actually larger than Nereid but harder to see due to its proximity to Neptune. The chapter on the moons also includes a table listing 61 features on Trition, all of them named after mythological marine creatures and places; for instance, Hirugo Cavus (Japanese jellyfish deity), Ravgga (Finnish fortune-telling fish-god) and



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A new camera for CCD users

Santa Barbara Instrument Group, California, is introducing a new CCD imaging camera, the model ST-5, designed for high-resolution imaging of objects containing fine detail. The ST-5 incorporates a new CCD detector with 10-micron-square pixels in a 320x240 format with an active area of 7.8mm^2. The combination of extremely small pixels, 14-bit dynamic range, regulated detector temperature, very low thermal noise, and an electronic shutter, make it well suited for planetary imaging and extended deep space objects containing structure and detail.

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Below: *The new ST-5 from SBIG.*

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Awib Dorsa (Namibian bushman word for rain).

The final pages briefly cover Pluto and a possible tenth planet, and are followed by appendices and an index.

As you'd expect, *Atlas of Neptune* is filled with beautiful Voyager 2 photographs of the planet, its moons and rings. Hunt and Moore's writing style is a bit clinical, but easily readable and clear. If your interest is the Solar System, you should add this book to your collection. **JN.**

An Introduction to Astronomical Photometry

by Edwin Budding
Cambridge University Press
272 pages, hardback, $99.00
ISBN 0 521 41867 4

An Introduction to Astronomical Photometry is a textbook on optical astronomical photometry intended for very advanced amateurs and early university students. Starting with an overview, the book moves on through the historical background, glossary of terms and underlying physical principles. From this base the current range of astronomical photometry is surveyed. The central two chapters deal with principles of photometer design, and data processing techniques. The remainder discusses analysing various kinds of variable stars including close binaries, spotted and pulsating stars.

This book is primarily aimed at the gap between a popularist approach and a full-scale research level textbook.

The Great Copernicus Chase

Owen Gingerich
Cambridge University Press
304 pages, hardback, $49.95
ISBN 0 521 32688 5

Owen Gingerich is a name familiar to readers of the American magazine, Sky & Telescope. In his regular columns for that magazine, Gingerich gives informative and often witty essays on the history of astronomy and the characters that often make it such a fascinating field to study.

Now, some of his columns have been brought together in a new book from Cambridge University Press - *The Great Copernicus Chase and Other Adventures in Astronomical History*. It should be an essential part of any astronomical library.

Ranging from ancient Egypt up to modern times, *The Great Copernicus Chase* gives an excellent introduction to the history of astronomy in an easily readable manner. We meet the giants of astronomy such as Galileo, Kepler, Einstein and Tycho but also others such as Ptolemy, James Link and Asaph Hall.

The book gets its title from the author's interest (or obsession) in tracking down first edition copies of Nicolai Copernicus'

---

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The Guide to the Galaxy

Nigel Henbest and Heather Couper

Nigel Henbest and Heather Couper take us on a personal tour of the Milky Way in this delightful guide to our home galaxy. Their lucid text is supported by a dazzling portfolio of colour photographs of stars, star clusters and gas clouds in the Milky Way.

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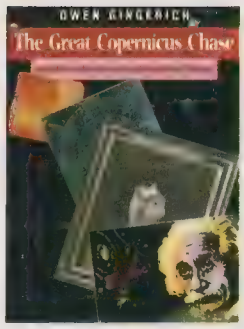
treatise *De Revolutionibus Orbium Coelstium* from around the world and then making a census of where each copy is located. Gingerich's travels have taken him from libraries ranging from the US Military Academy at West Point to the archives of the Roman Catholic Church in Vatican City. The author also searched in private collections which often have purchased copies sometimes for very little money and sometimes for vast fortunes. Gingerich also reveals some of the problems that he has had with overzealous bureaucrats and suspicious collectors.

One of the most fascinating chapters in the book concerns the contribution that Islam has made to astronomy. During the Dark Ages in Europe, Islam



scholars carried the torch that had been passed on by the ancient astronomers and made many impressive discoveries. It is thought that Copernicus was influenced by Ibn al-Shatir who studied planetary mechanisms in great detail. This idea is usually ignored by Western writers of astronomical history.

Another interesting chapter is a complete and unbiased view of Galileo's infamous trial by the Roman Catholic Church. Using documents from Vatican archives, Gingerich has reconstructed the trial that led to Galileo becoming a martyr to the scientific community. Other subjects include the musical career of William Herschel who discovered the planet Uranus, mysterious nebulae and the 'Great Comet' of 1965.

My only complaint is the lack of mention of the role of women in astronomy. This is a common fault with many astronomy books, but hopefully this will change as women make greater progress in the field. That aside, *The Great Copernicus Chase* is an exceptional book and is suitable reading for anyone interested in astronomical history, whether they know little or a lot about the subject. **Kate Doolan.**

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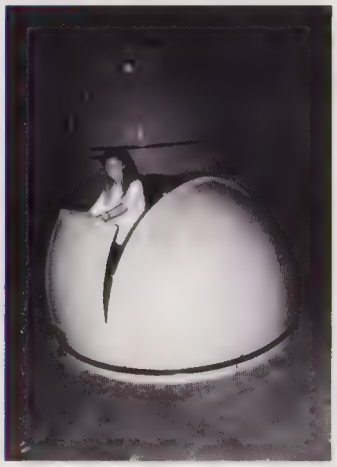

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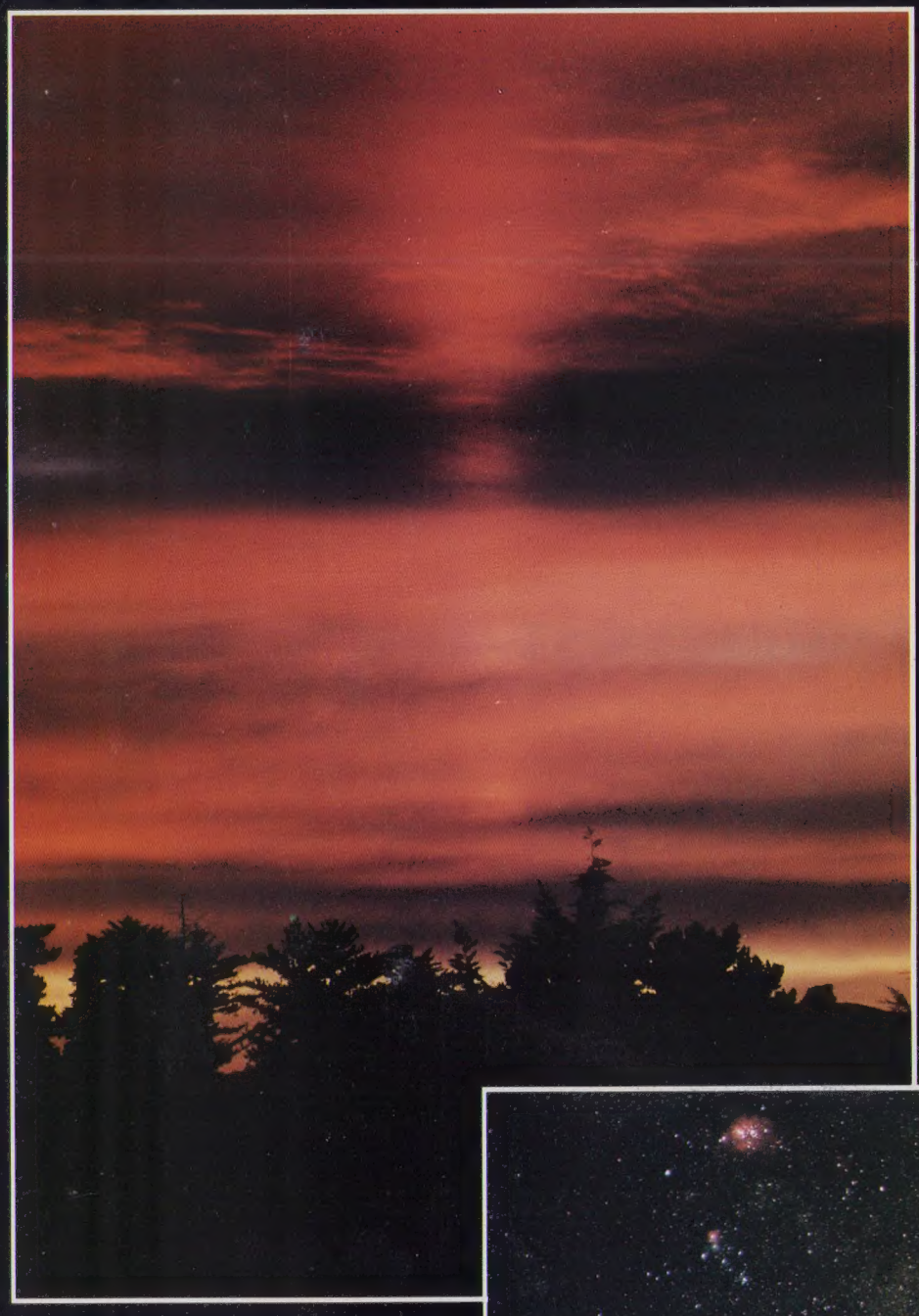
Readers' Photos

Above: Zac Pujic (St Lucia, Qld) took this image of the Andromeda Galaxy using a 52cm f/3.4 Newtonian telescope at the Puimichel Observatory in France. It's actually a composite print of 16- and 20-minute exposures on Fuji 1600 print film. It just goes to show what a bit of aperture and altitude can do!

Right: The supergiant star, Alpha (a) Persei (the bright orange star to the left of centre), is the brightest star in the northern constellation Perseus. At a distance from the Earth of around 620 light-years, Alpha is a member of a slow-moving cluster of stars. Photo by Chii-Sheng Lin (Taiwan), using a Nikkor 300mm f/4 lens and Nikon FM2 camera, 30 minutes exposure on Fuji SHG400.



Left: N. Kenwright (Havelock North, NZ) is a physics teacher who keeps an eye on the sky. He snapped this photograph of a sun column at 6.30am one December morning last year. This is a 1/30th-second exposure on Kodacolor Gold 100 ASA.

Below: One of the most magnificent sights in the sky is the globular star cluster, Omega Centauri. Steve Little (Qld) took this 5-minute exposure on Konica SR-V3200 film through a 15cm f/5 Newtonian telescope - unguided!

Right: Jenni Kay (Lobethal, South Aust.) writes that what she most enjoys about astrophotography is sitting with her photo album, identifying deep sky objects on the photos she has taken. And if you pick the right part of the sky, you can capture many different objects in the one frame. In this shot of Sagittarius, Jenni can find 10 Messier objects - how many can you find? Jenni piggybacked a 135mm lens and Nikon camera on her 20cm Schmidt-Cassegrain telescope for this 6-minute exposure.

Above: Bob Slobins is one of our US readers, and an expert at eclipse photography. This is the November 29, 1993, eclipse, which was not visible to us in the south. Bob used a Canon F-1 camera and 400mm lens at f/8. The exposure was about 25 seconds on Fuji NHG400 film. The camera and lens were piggy-backed on a Meade 2080 LX-3 telescope, tracking at the lunar rate. Photo courtesy of R.B. Slobins/Phototake.

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This issue's winner: Zac Pujic, for his photo of the Andromeda Galaxy (page 65).

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